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Atlanta, Georgia 30332

GEORGIA TECH 1885-1985

DESIGNING TOMORROW TODAY

THE GEORGE W. WOODRUFF SCHOOL OF MECHANICAL ENGINEERING

ME 4182
MECHANICAL DESIGN ENGINEERING

NASA/UNIVERSITY
ADVANCED MISSIONS SPACE DESIGN PROGRAM

SANDBAG FILLING IMPLEMENT

JUNE 1987

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SANDBAG FILLING IMPLEMENT

GROUP 5

Executive Summary

The lunar soil bagging group has designed a machine that collects and bags lunar soil for the purpose of placing these bags on lunar habitats. The lunar soil bagging group is recommending that a flexible brush be used to pitch the soil into a hopper. The soil in the hopper is then used to fill bags. When the bags are filled with the supply of soil, the skitter will then move to a new location and repeat the process.

Overall dimensions of the machine are a height of 3.10 meters, depth of 1.22 meters, and a width of 2.44 meters. The volume the bagger will require in the space shuttle is 9.228 cubic meters. The mass of the soil bagging and collection machine is 2,700 kilograms. This will produce a force on the moon of 4,444 newtons (1,000 lb_f).

The system will produce an average of one bag of soil, approximately 0.057 cubic meters (2 ft^3), per minute. Each cycle of the bagging system collects a maximum of 0.454 cubic meters (16 ft^3), enough soil to fill eight (8) bags.

The energy requirements of the soil collection and bagging machine will be supplied by a 25 kW fuel cell.

INTRODUCTION

The project of designing lunar equipment was initiated under the NASA Advanced Missions Program in conjunction with Michigan State University. Future space developments include establishing a lunar base which will serve as a scientific outpost and catalyst to space exploration. This lunar base will initially consist of modules about the size of two large buses. The modules must be protected from ultraviolet radiation, meteor bombardment, and temperature extremes. A feasible way of providing this protection is to cover the modules with a layer of soil 1.83 meters (6 feet) deep.

Three methods of covering the modules have been considered. The first one is to simply pile loose soil on top of the module. Drawbacks to this scheme include the difficulty of maintaining a constant thickness of soil on the module, and the inherent possibility of damaging the module upon removing the soil.

The second method is to manufacture bricks from the regolith and stack them around the module. This method is currently being investigated by other engineers.

The third method, a method we chose to investigate, involves collecting the soil, bagging the soil, and placing the bags around the module. The equipment to perform these tasks will attach directly to a three-legged walker, called a skitter, and will depend on its mobility to collect the soil.

We have designed a system that collects soil by brushing, and then tightly seals it in bags. This lunar soil bagging system utilizes exert equal and opposite forces and the skitter, and has a production rate of about one bag per minute.

BACKGROUND

The concept of "bagging" lunar soil for protective shielding in an offspring of Project LEAP (Lunar Ecosystem and Architectural Prototype). Project LEAP involves the design of a manned lunar base with a focus on a lunar settlement. The bagged soil is needed to protect against: micro-meteoroid bombardment, radiation, and the thermal extremes of the lunar environment. The temperature range on the moon is as much as +93 C to -157 C. The moon has no radiation-absorbing atmosphere or magnetic field to deflect radiation. Meteoroids that would burn up or be slowed considerably in the earth's atmosphere are unimpeded in the lunar vacuum and strike at high velocities. The impact energy is so great that the meteoroid explodes and excavates a mass of material up to 1,000 times that of the projectile.

A logical solution to these problems is to bag lunar soil (regolith) and place it to a sufficient depth to provide adequate shielding for the lunar facilities and personnel. It has been estimated that 2 to 3.5 meters of soil could insulate the modules against the thermal extremes, protect against micro-meteoroid bombardment, and limit crew radiation levels to acceptable levels. However, a depth of 2 to 3.5 meters of soil surrounding the habitation modules of the lunar base implies a large amount of heavy construction in a hostile environment. An automated system should limit crew EVA (ExtraVehciular Activity) time. The system should bag the soil to accomplish dense packing to optimize shielding value, and facilitate easy handling with little dust. Thus the creation of an automated lunar soil bagging system is necessitated.

OVERVIEW

The lunar soil bagging machine is a machine that collects and bags lunar soil. The bags of soil are to be placed on lunar habitat modules to protect the occupants from the harsh lunar environment. Our machine uses two brushes to collect the soil and pitch it into a hopper. From the hopper the soil is used to fill bags, the bags are then ejected from the machine through a door on the bottom of the bagging platform.

The two brushes on this machine are located on each side of the structure and pitch lunar soil into a centralized hopper. The diameter of the brush has been optimized so that it delivers maximum performance at a depth of 7.6 cm (3 inches). The angular velocity of the brush is controlled so that the brush will pitch the soil into the hopper as the distance from the brush to the hopper changes. The area the brush will sweep is equal to the width of the brush times the length of the retractable booms holding the brush. These retractable booms will pull the brush toward the platform along the lunar surface. When the brush gets to the structure the brush will move up an inclined plane toward the hopper.

Once the soil is in the hopper it will be metered into a 0.057 m^3 (2 ft^3) bag by a sliding shuttle. The bag will be made of teflon and be constructed of two separate sheets. Each bag will be assembled just before it is needed. A mechanical seal is used to seal the bag. Pressure bars are used to close the mechanical seals.

When a cycle of the bagging system is completed, the skitter will rise and a hatch in the floor of the bagging platform will open. All of the bags that have been filled will be dropped through the floor of the bagging platform and be left for collection and transportation to the living modules.

DISCUSSION

SYSTEM

COLLECTION

INTRODUCTION

The collection system for the Lunar Soil Bagging System is responsible for collecting the top 7.6 centimeters of the lunar surface leaving behind the particles larger than ten centimeters in diameter. This was accomplished through the application of a rotating brush mounted on an actuated boom. As the brush is drawn toward a centralized hopper its rotation pitches lunar dust particles into the hopper.

OPERATION

In the proposed collection system two brushes are initially positioned 2.44 meters from the base of the bagging system platform. These brushes are located on opposite sides of the platform to employ the balancing effects of equal and opposite forces. Due to the almost complete vacuum atmosphere the particles follow a path predicted from Newtonian physics equations. As the brush is drawn toward the platform the initial angular velocity of seventy-five revolutions per minute is reduced to insure an optimum trajectory is followed.

Since it cannot be assured that all of the particles will fall into the hopper, once the brush has reached the platform it will "sweep" the remaining dust up the ramp into the hopper.

Once completing this operation the brush will be held inboard until the next time collection is initiated.

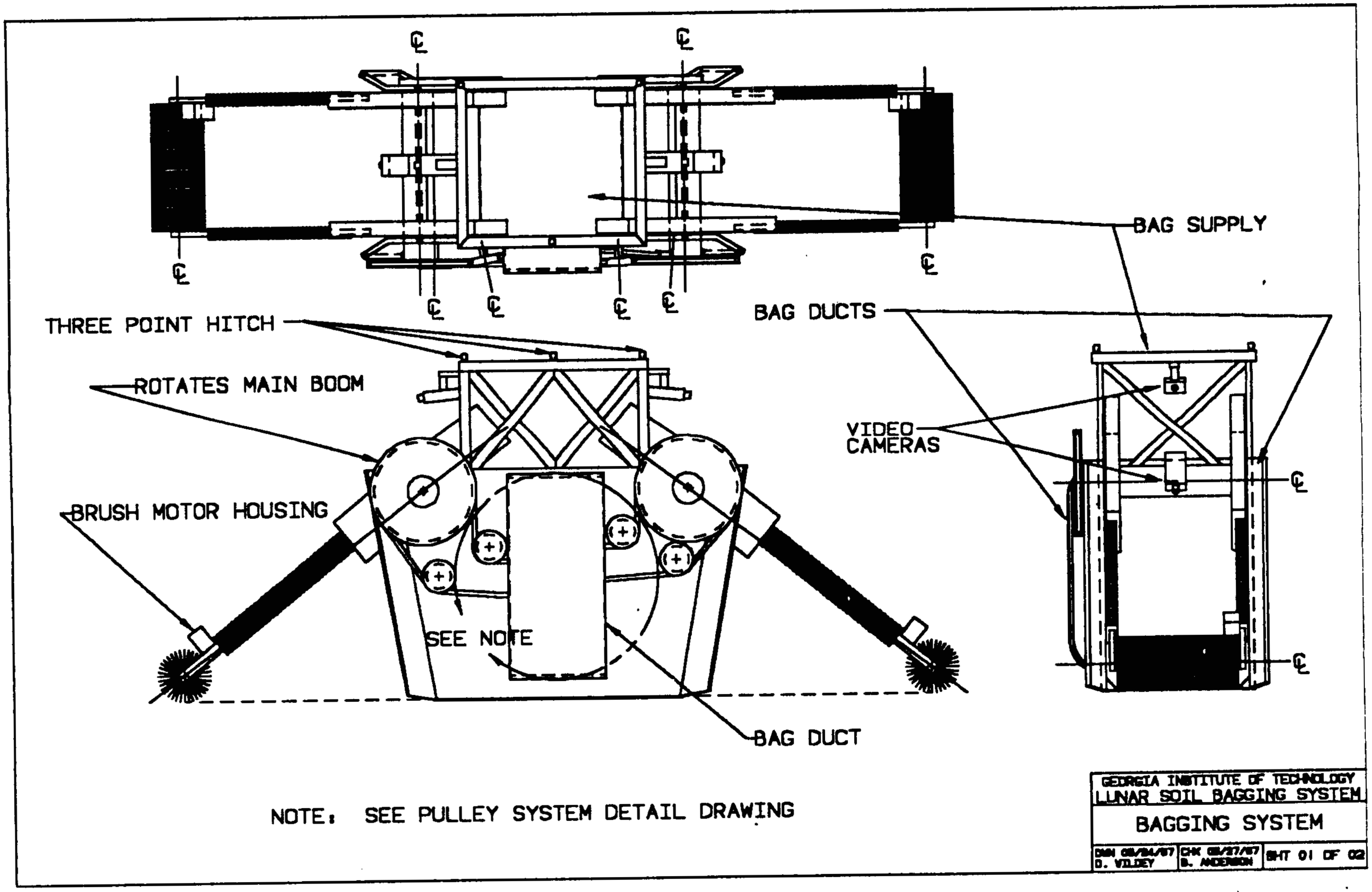
In the event that a brush reaches a particle protruding more than eight centimeters above the surrounding regolith (see Sensors for discussion), both brushes will be lifted so that one of them will clear this obstacle and the other will not create a moment on the skitter while the other brush would be disengaged from the soil.

HARDWARE

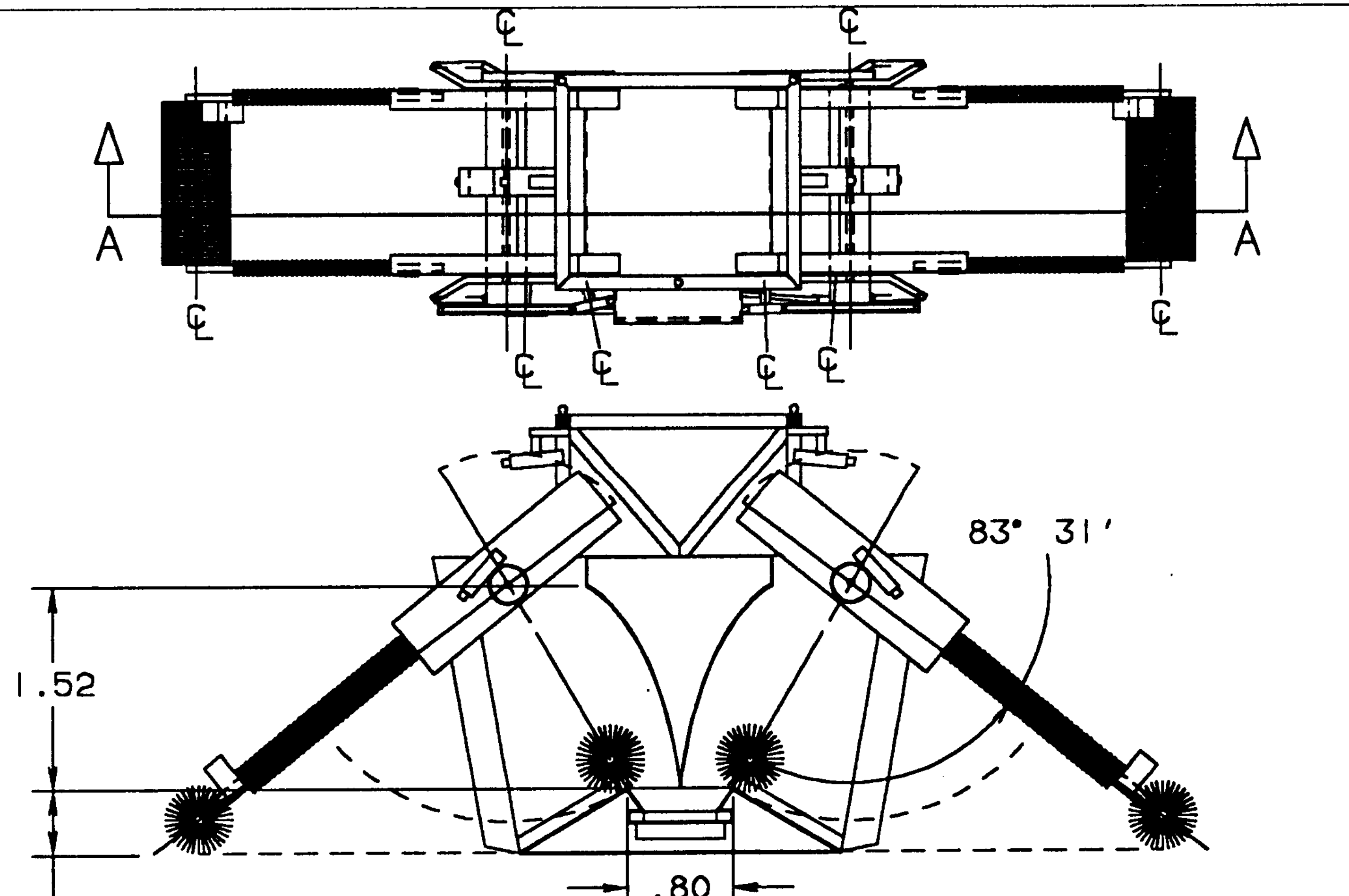
The collection system is composed of three basic elements: the brushes, the actuators, and the platform/hopper. The brushes are designed to be flexible, wear resistant, and efficient. The actuators must be strong enough to support the load, sealed from the harmful effects of the dust, fast enough to complete the entire operation in ninety seconds, wear resistant, and have two degrees of freedom (see Power Transmission for discussion). The platform/hopper is designed to be wear resistant and wide enough to catch most of the particles and allow for the brush to "sweep" it clean.

The brushes were designed with a 25.4 centimeter radius (see Figure 1). This insures that the initial angle of trajectory of the particles is approximately forty-five degrees or less depending on the depth the brush is beneath the soil. Speed control will be used to control the rotation speed of the brush in order to produce the proper trajectory. This will insure optimum efficiency since the forty-five degree trajectory is fixed. The brush is designed to be flexible enough so that it will pass around some particles (see Materials for discussion) but this flexibility may also contribute to a loss in trajectory angle.

The opening at the side of the platform is designed 20 centimeters wider than the brush and 2.23 meters high. This encourages high collection volumes without over stepping the general parameters necessary for the skitter to operate. Over the centralized hopper are elliptical directing plates which aim the incoming particles down, toward the hopper. The hopper is designed with sloping sides and its capacity is intended to include heaping of the soil.



BAG SUPPLY
THREE POINT HITCH
BAG DUCTS
ROTATES MAIN BOOM
VIDEO CAMERAS
BRUSH MOTOR HOUSING
SEE NOTE
BAG DUCT
NOTE: SEE PULLEY SYSTEM DETAIL DRAWING
GEORGIA INSTITUTE OF TECHNOLOGY
LUNAR SOIL BAGGING SYSTEM
BAGGING SYSTEM
DWN 08/24/87 D. VILDEY
CHK 08/27/87 B. ANDERSON
SHT 01 OF 02



SECTION A-A

GEORGIA INSTITUTE OF TECHNOLOGY LUNAR SOIL BAGGING SYSTEM		
SOIL BAGGING SYSTEM CROSS SECTION		
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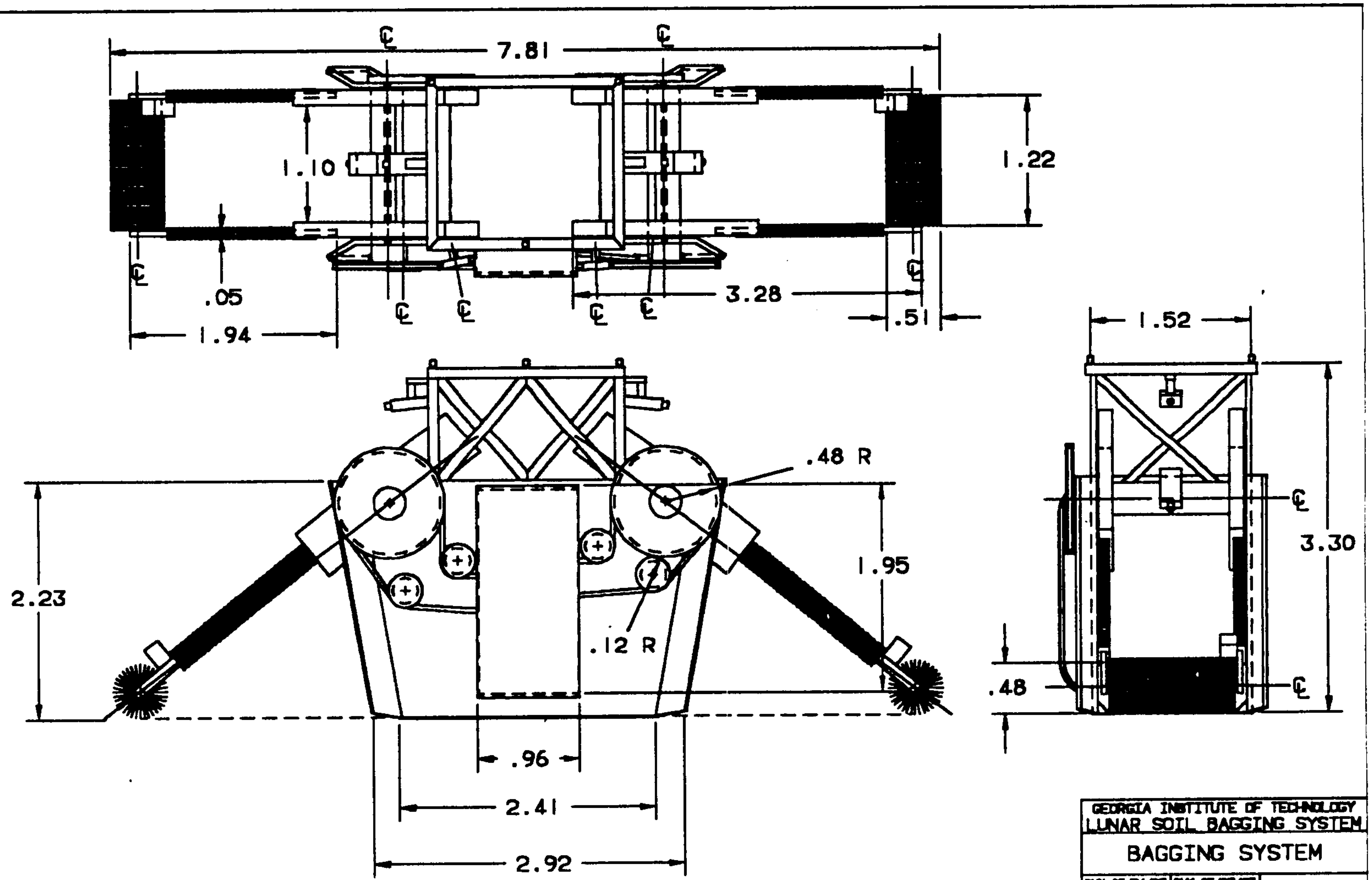
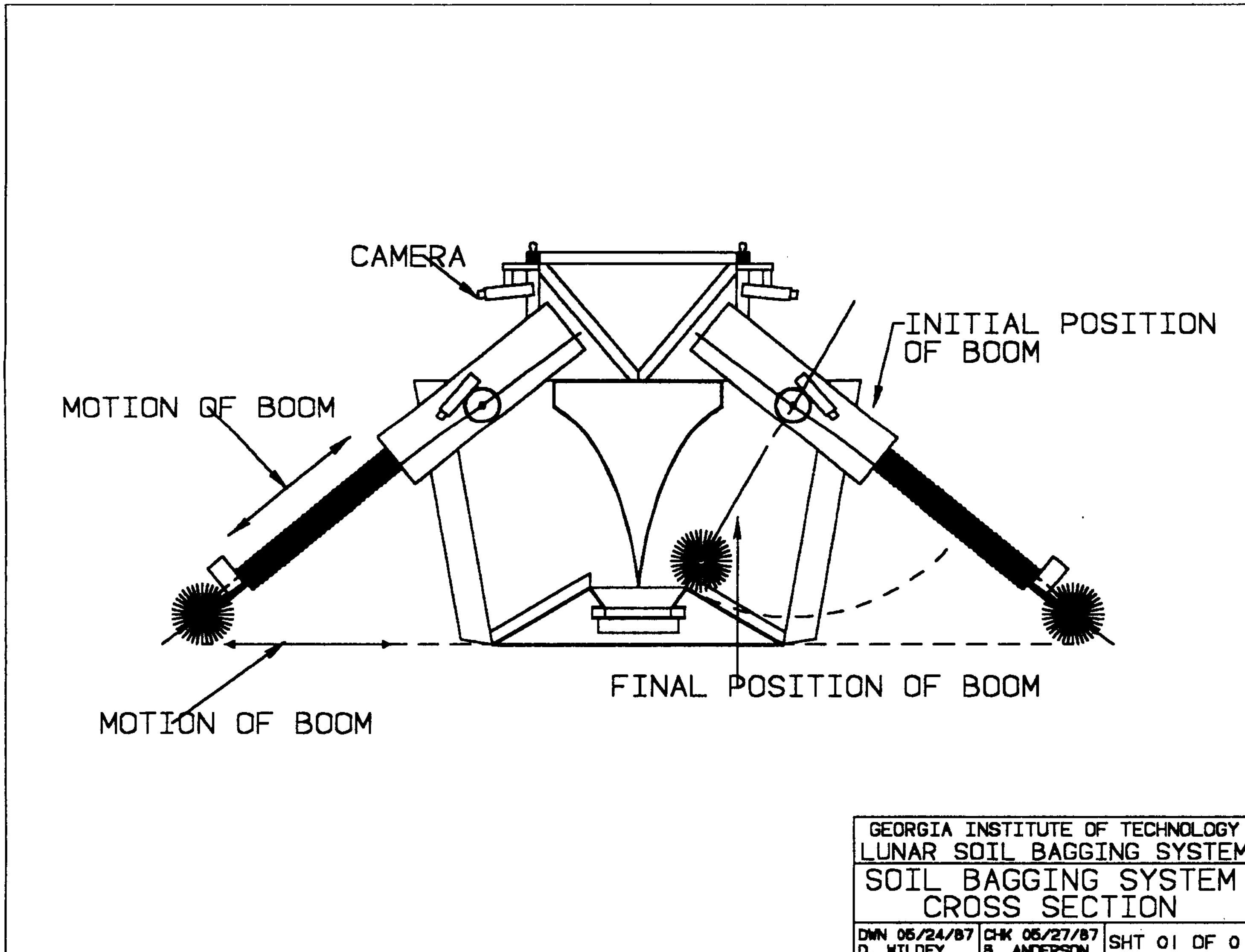
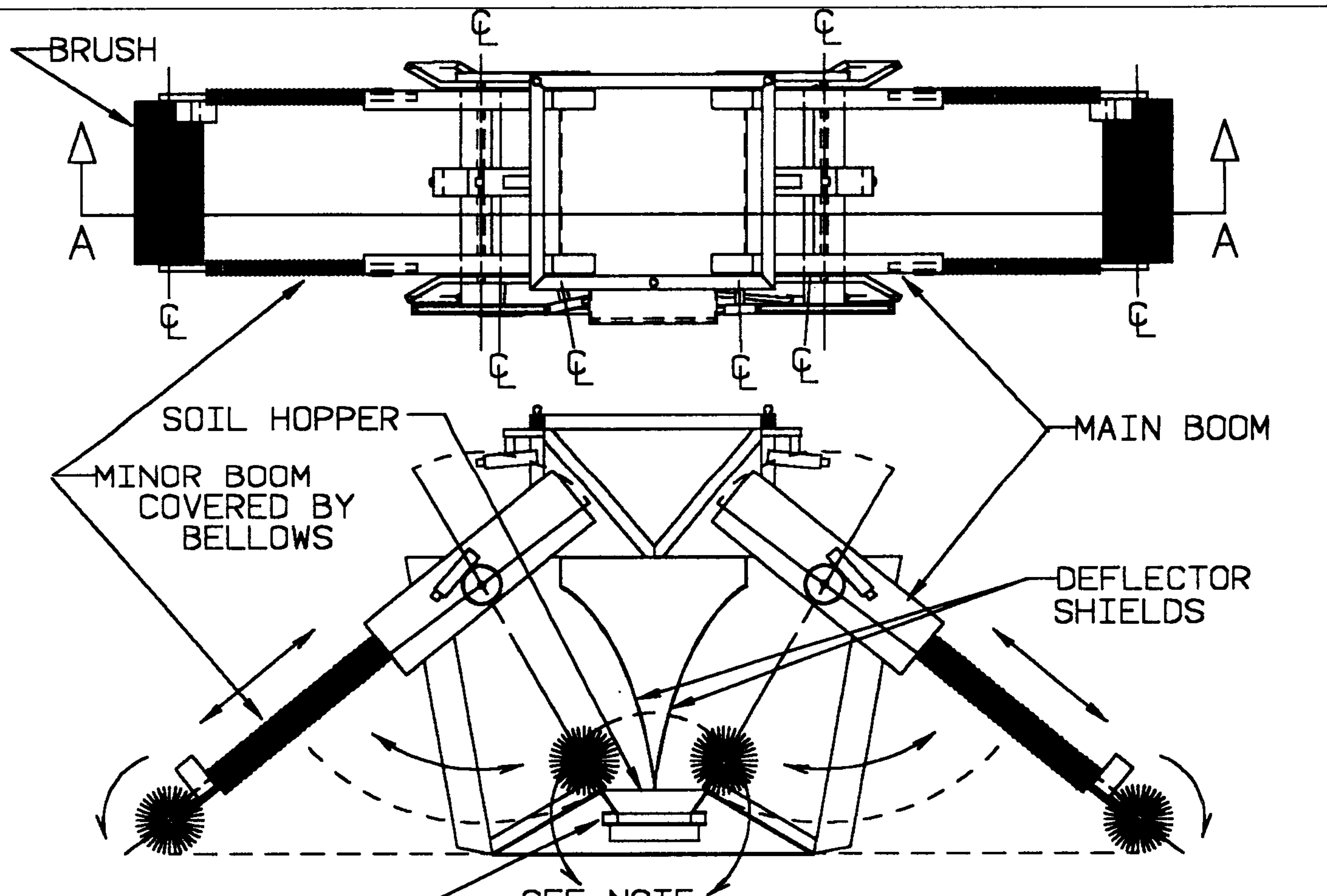

7.81
1.10
1.22
.05
1.94
3.28
.51
1.52
3.30
.48 R
.12 R
2.23
1.95
.48
.96
2.41
2.92
GEORGIA INSTITUTE OF TECHNOLOGY
LUNAR SOIL BAGGING SYSTEM
BAGGING SYSTEM
DWN 08/24/87
D. WILDEY
CHK 08/27/87
B. ANDERSON
SHT 02 OF 02


CAMERA
INITIAL POSITION OF BOOM
MOTION OF BOOM
MOTION OF BOOM
FINAL POSITION OF BOOM
GEORGIA INSTITUTE OF TECHNOLOGY
LUNAR SOIL BAGGING SYSTEM
SOIL BAGGING SYSTEM CROSS SECTION
DWN 05/24/87 D. WILDEY
CHK 05/27/87 B. ANDERSON
SHT 01 OF 01



SECTION A-A

NOTE: SEE BAGGING SYSTEM DETAIL DRAWING

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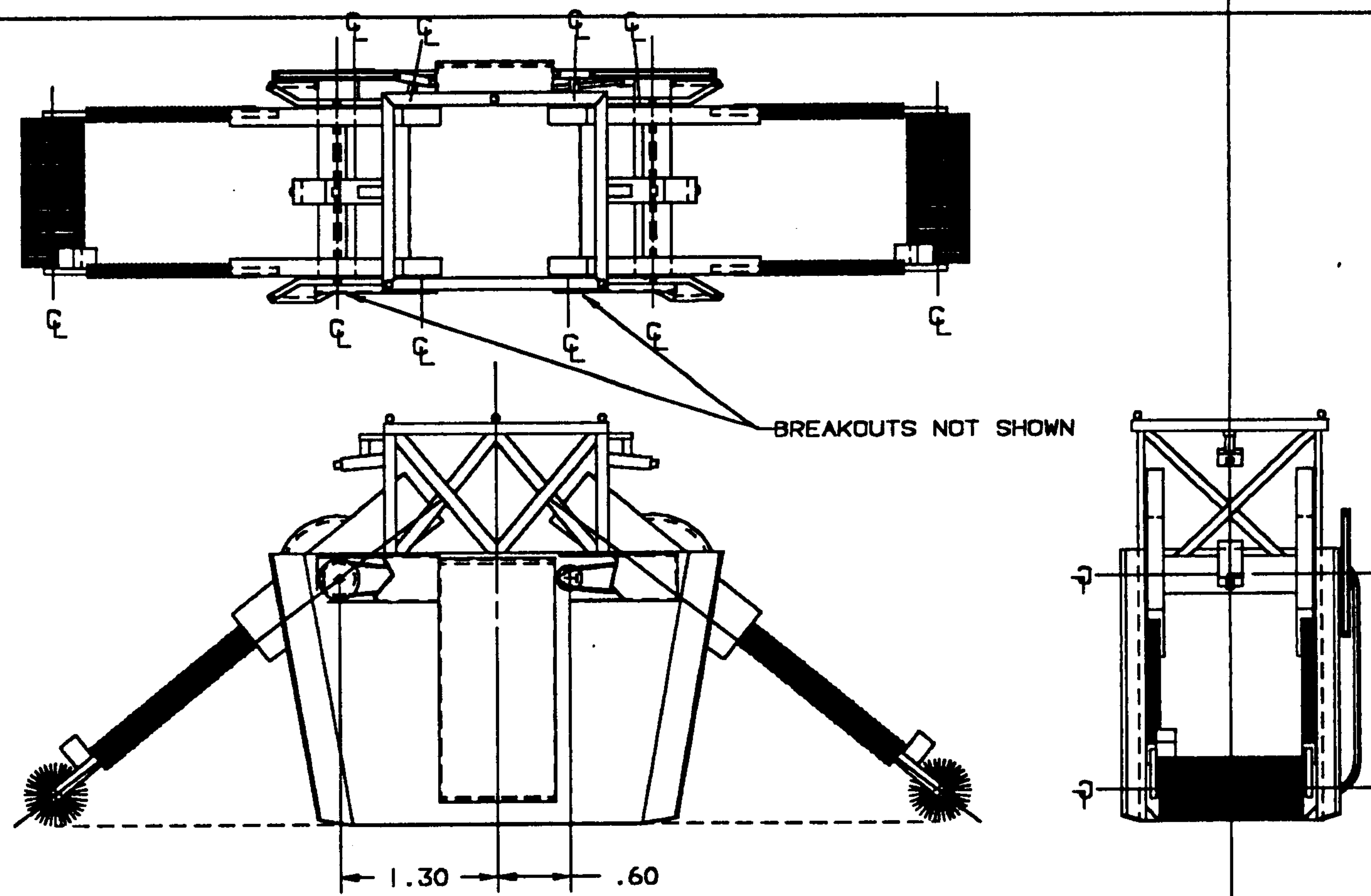
SOIL BAGGING SYSTEM CROSS SECTION		
DWN 05/24/87 D. WILDEY	CHK 05/27/87 B. ANDERSON	SHT 01 OF 02

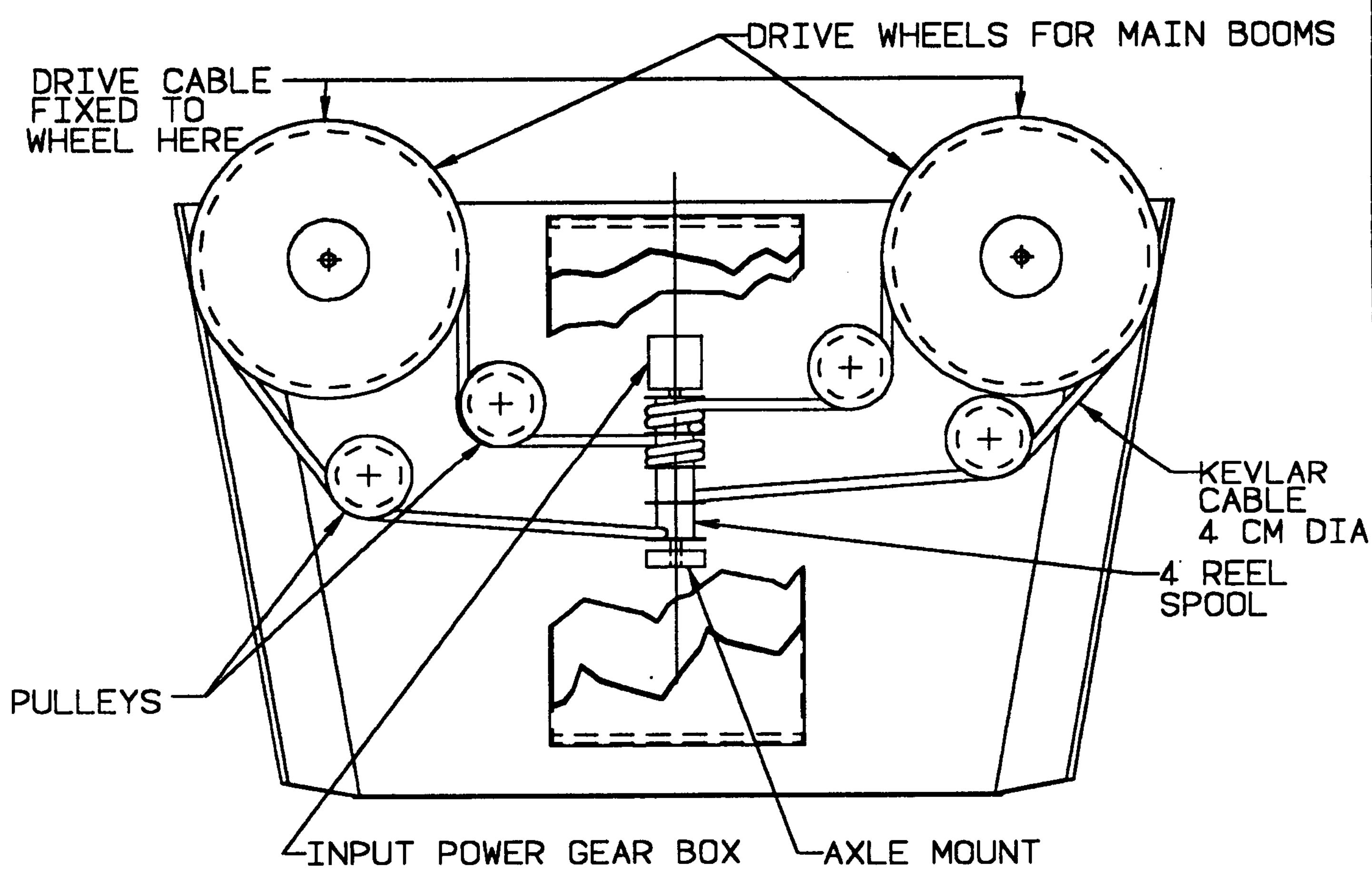


NOTE A: SEE PULLEY SYSTEM DETAIL DRAWING

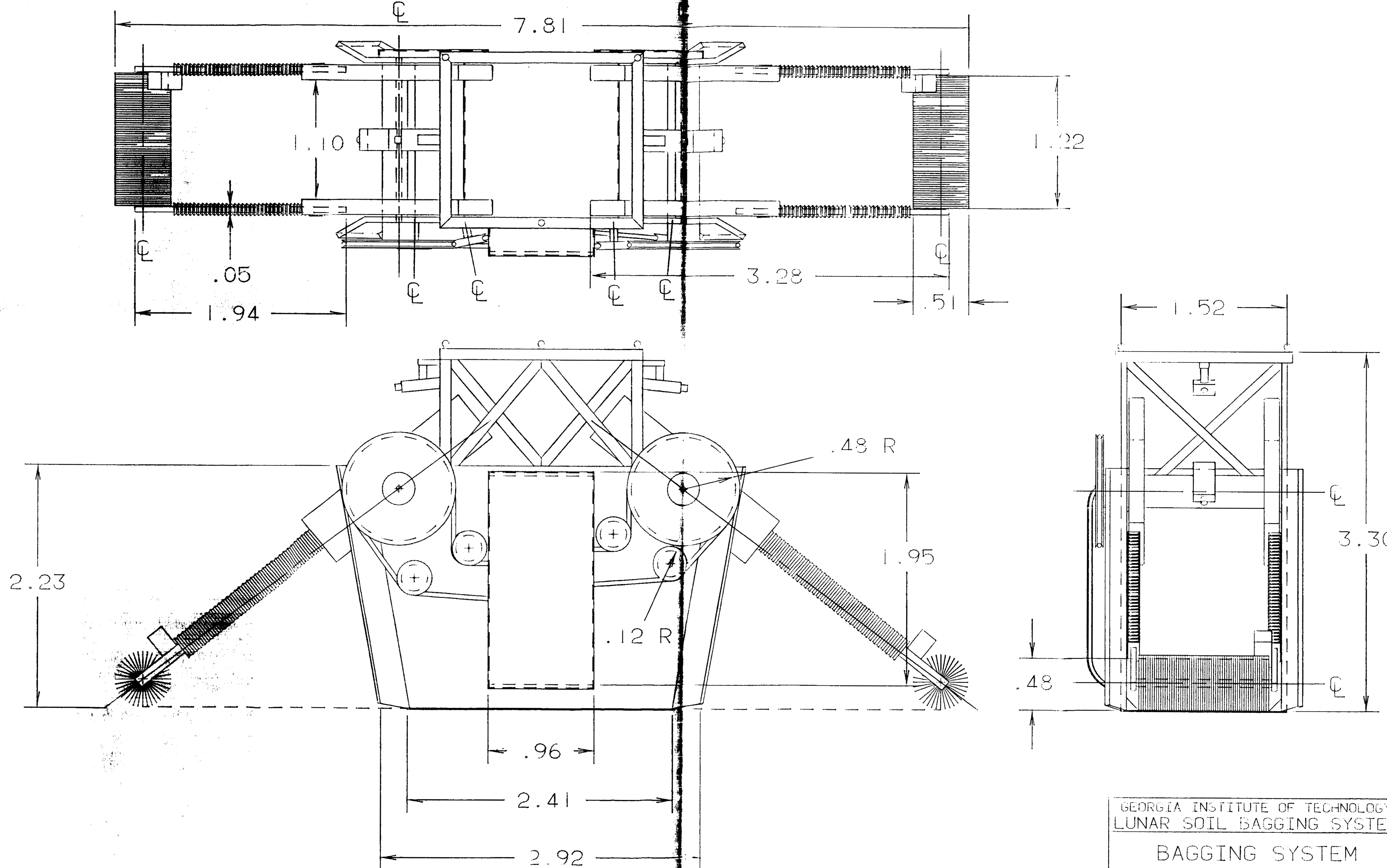
GEORGIA INSTITUTE OF TECHNOLOGY
LUNAR SOIL BAGGING SYSTEM

BAGGING SYSTEM

DWN 08/04/87 D. WILDEY	CHK 08/07/87 B. ANDERSON	SHT 01 OF 01



GEORGIA INSTITUTE OF TECHNOLOGY		
LUNAR SOIL BAGGING SYSTEM		
PULLEY DETAIL		
DWN 06/04/87 D. WILDEY	CHK 06/04/87 R. BARRETT	SHT 01 OF 01



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BAGGING SYSTEM		
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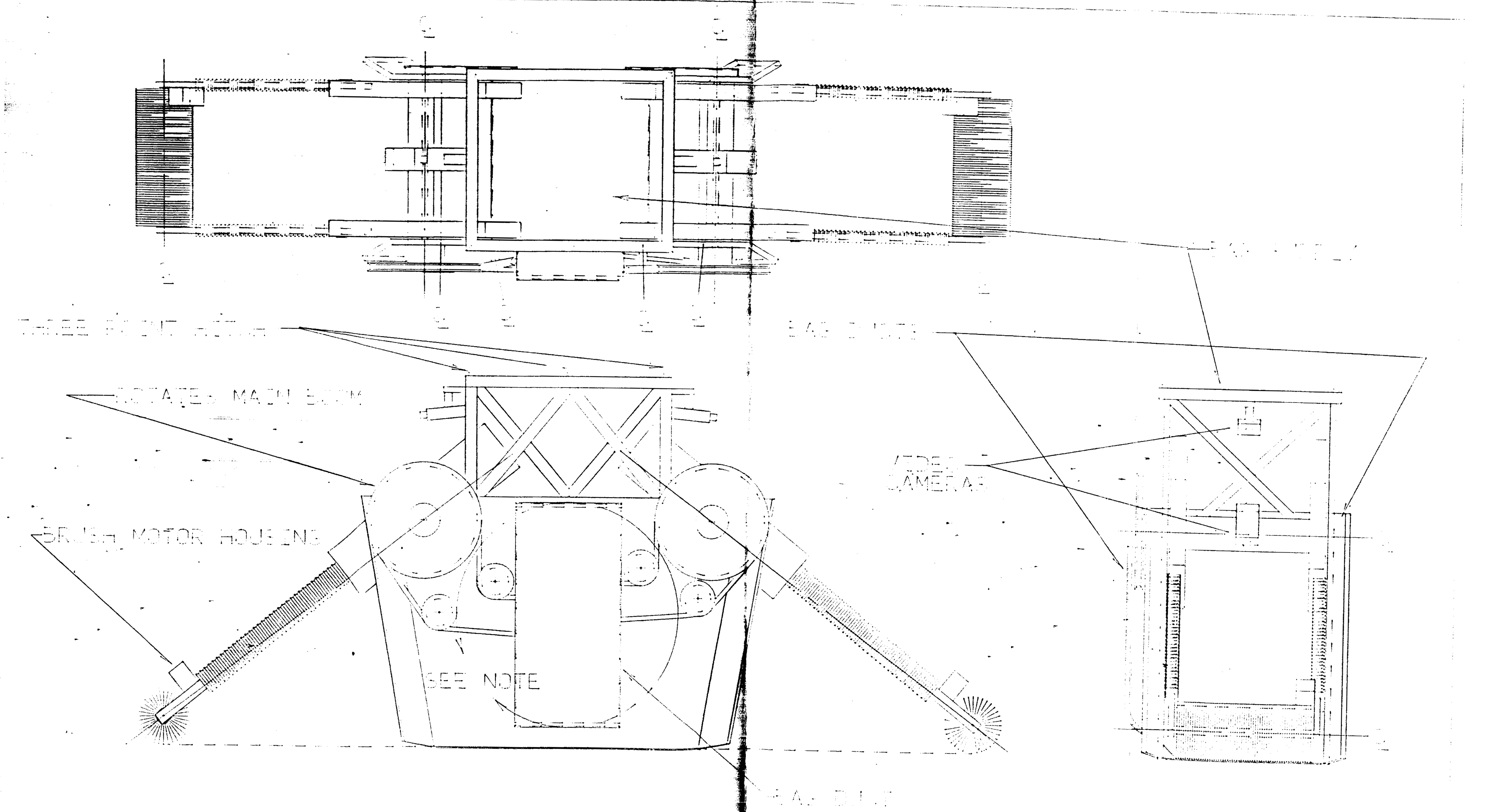
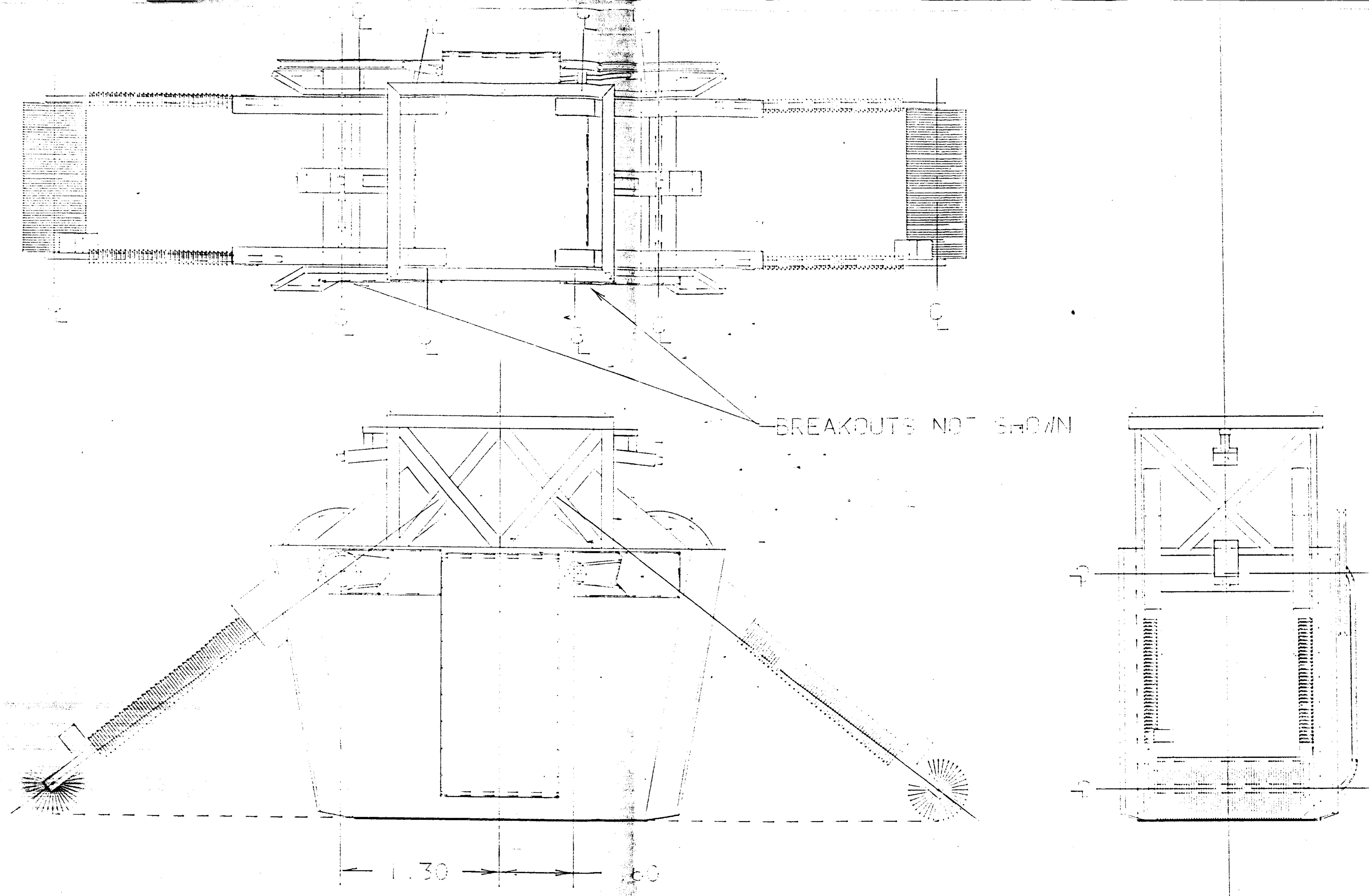


NOTE: SEE PULLEY SYSTEM DETAIL DRAWING



NOTE A: SEE PULLEY SYSTEM DETAIL DRAWING

GEORGIA INSTITUTE OF TECHNOLOGY
LUNAR FILL BAGGING SYSTEM

BAGGING SYSTEM

BAGGING SYSTEM

After the brushes have finished filling the platform, the skitter is lifted and the bagging system is activated. This system forms bags from rolls of plastic film, fills them with soil, seals the bags, and drops them to the lunar surface.

Each bag is 0.765 m x 0.304 m and holds approximately two cubic feet of lunar soil. The bags are formed by sealing together the edges of two sheets of 15% carbon filled Teflon TFE plastic. The edges formed by the two sheets of plastic are sealed together with a mechanical, zip-loc type seal. This zip-loc seal is referred to as the sealing mechanism and will be designated as either the male or female half of the system. (See Figure 2).

The bags are stored on two continuous rolls with the male and female halves of the sealing system on opposite rolls. The sheets are passed around a hollow elliptical form (a = 0.275m and b = 0.088m) and pulled through two pairs of pressure rollers by gears. As the plastic moves through the roller bars, the mated seals are pressed together, thus forming a continuous tube of plastic. This newly formed seal is referred to as the side seal of the bag.

Once the sides of the bag have been formed, soil is metered into it through the elliptical form. (The bottom of this bag was sealed in the previous cycle). After filling is completed, two pressure pads press the male and female sealing mechanisms together,thus sealing the top of the bag just filled and also sealing the bottom of the next bag. Finally, the filled bag is cut off by a retractable blade in the center of the pressure pads. The cycle is then repeated.

The soil that has been gathered by the collection system is deposited into a centralized hopper. Beneath this hopper is the bagging system. The hopper has an elliptical hole in its bottom equal in size to the elliptical form described above, and it is temporarily sealed by a movable shuttle device. The hollow elliptical form used to shape the bags is located beneath this hole and is located 0.24 m from the center line of the hopper.

A shuttle device located in the platform is used to meter soil from the hopper into the bags. A 1 hp motor and cam system slides it back and forth in its track between the hopper and bag side of the platform. The shuttle is a metal plate with an elliptical hole identical to the one in the bottom of the hopper. This hole has a volume of 5,660 cubic centimeters and is referred to as the cup. On the hopper side, the cup is directly underneath the hopper and fills with soil. On the bag side, the cup is over the opened bag and empties through the elliptical form into it. Any particles that may get trapped between the shuttle cup and the surfaces surrounding it will be sheared by the force of the motor (see Figures 3 and 4).

The bagging system is designed to be a continuous feed system. That is, the shuttle and the bags do not stop moving until all of the soil has been bagged. As the pressure pads form the top seal of the newly filled bag and the bottom of the next one, the shuttle is returning to the hopper side of the platform to be refilled. The filled bag is cut away from the roll as the shuttle begins to empty the first cup into the next bag.

Each bag requires ten cups or cycles of the shuttle to be filled. This takes approximately 20 seconds. Closing the bags requires a little less than two seconds to complete. This allows the shuttle to keep moving as the bags are feeding down. The total time required to fill and close one bag is approximately 22 seconds.

To allow for automatic bag refilling, the two rolls of bags are stored on a disposable frame. This assembly will be referred to as the bag cartridge. Each cartridge is designed to hold enough bag material to make 1800 sandbags. It will therefore require cartridges to produce the sandbags needed to cover the lunar outpost.

The cartridges are loaded from above through the equilateral triangle opening of the skitter. They slide down along simple guide rails and lock into place.

The initial three meters of each roll is a 5 mill aluminum leader whose purpose is to allow the plastic film to be fed through the bagging system and into the pressure roller gear assembly. This leader is locked in place by a pair of gears on the cartridge. These gears are designed to mesh with a lead-in gear on the bagger assembly. This lead-in gear pulls the plastic into a three centimeter duct which guides the film into the bag sealing system. The leader is fed through the entire bagging system and is cut off by the blade in the pressure bar.

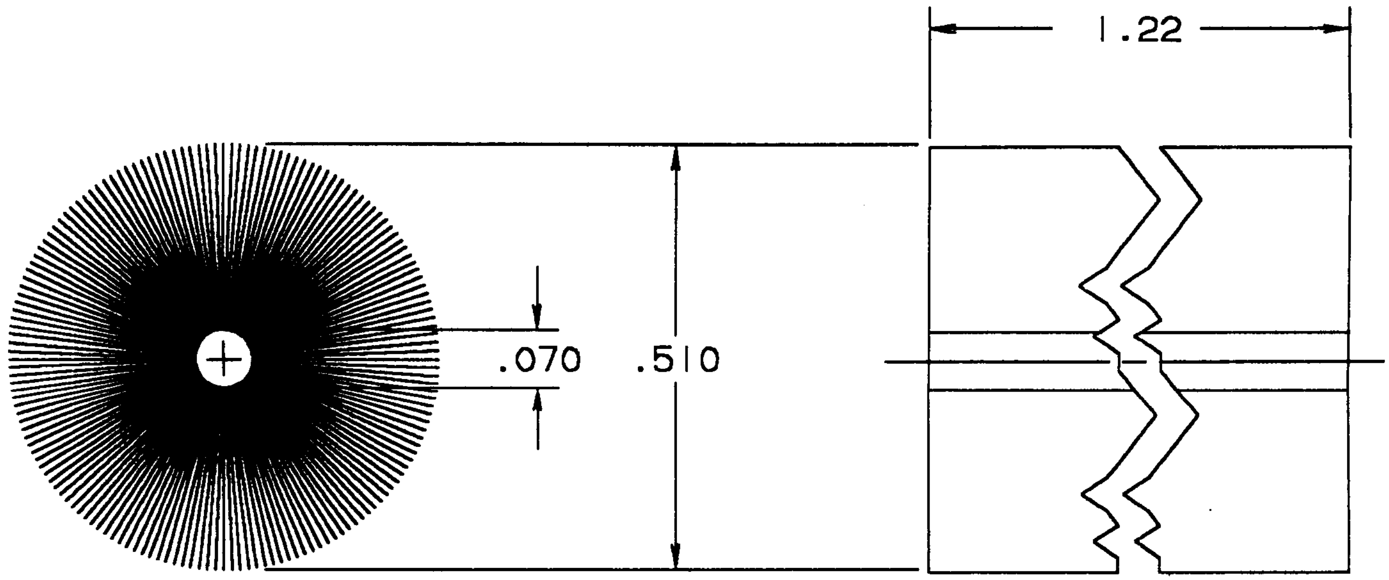
The bag sealing system consists of two components, the side sealing equipment and the bottom and top sealing equipment. The fundamental component of the side sealing system is the pressure roller and gear combination (See Figure 4). The pressure rollers press the male and female halves of the sealing mechanism together. They are 4.99 cm in radius with a maximum clearance of 5.08 x 10^-4 m between them. Smaller clearances are acceptable because the Teflon bag material will compress, allowing the seal to be formed.

Attached to the pressure rollers about the same axis are the gears which pull the plastic into the rollers. The teeth of these gears are designed to mesh with every other sprocket hole on the bag rolls allowing every gear tooth to occupy its own hole without damaging the Teflon film.

These gears are connected to a 1 hp motor by a series of idler gears and a gear reduction box. One motor drives both pairs of pressure roller and gear combinations.

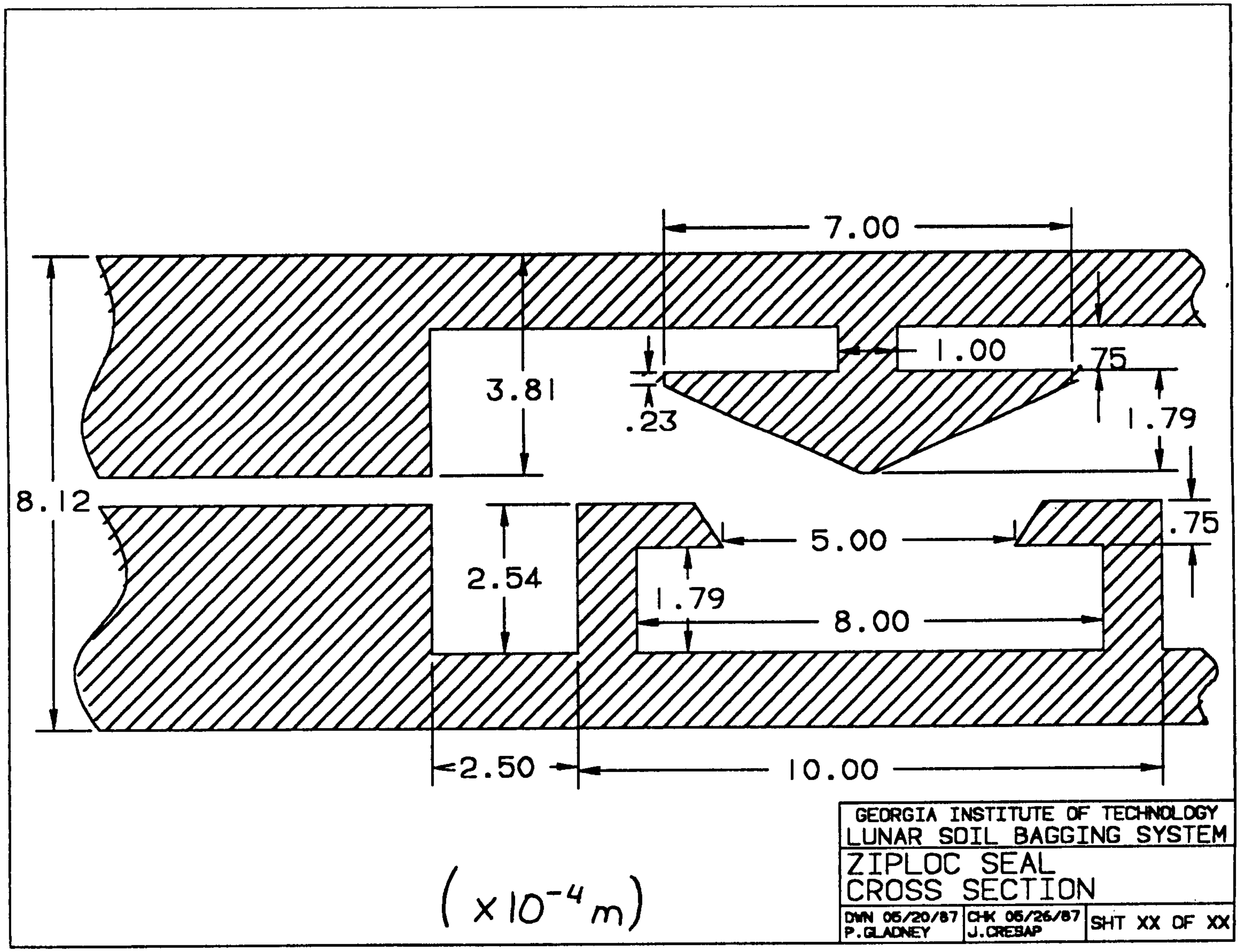
The bottom and top sealing system consists of two 4 x 4 cm pressure bars each 0.65 m in length. Each bar remains fully retracted at rest, out of the path of the moving bags. A bar code on the edge of the bag signals the system when to close.

To close, both bars move forward to the center of the elliptical form and press the sealing mechanism together. The pressure bars are each moved forward and backward by a 1/2 hp motor. These motors are attached to a set of reduction gears which in turn drive a gear rack attached to the center of the pressure pad. At the end of the cycle, when the pads are pressed together, a blade extends from one pad into a slit in the other one to cut the bags apart after they are filled.



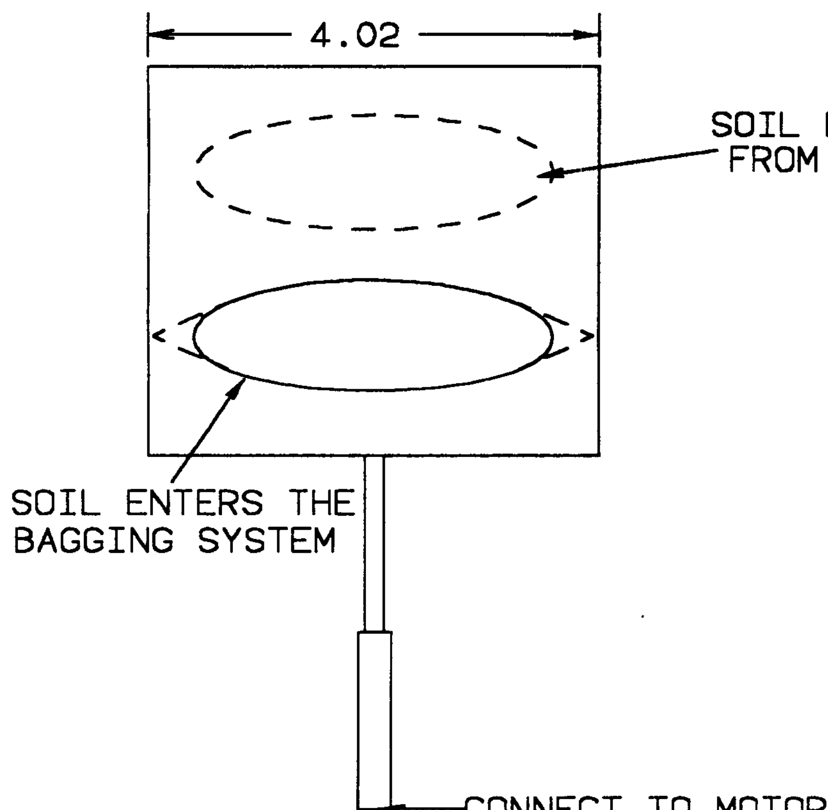
NOTE: BRISTLE SPACING @ 2.25 DEGREES

GEORGIA INSTITUTE OF TECHNOLOGY LUNAR SOIL BAGGING SYSTEM		
SOIL COLLECTION BRUSH		
DWN 05/24/87 D. WILDEY	CHK 05/24/87 B. ANDERSON	SHT 01 OF 01

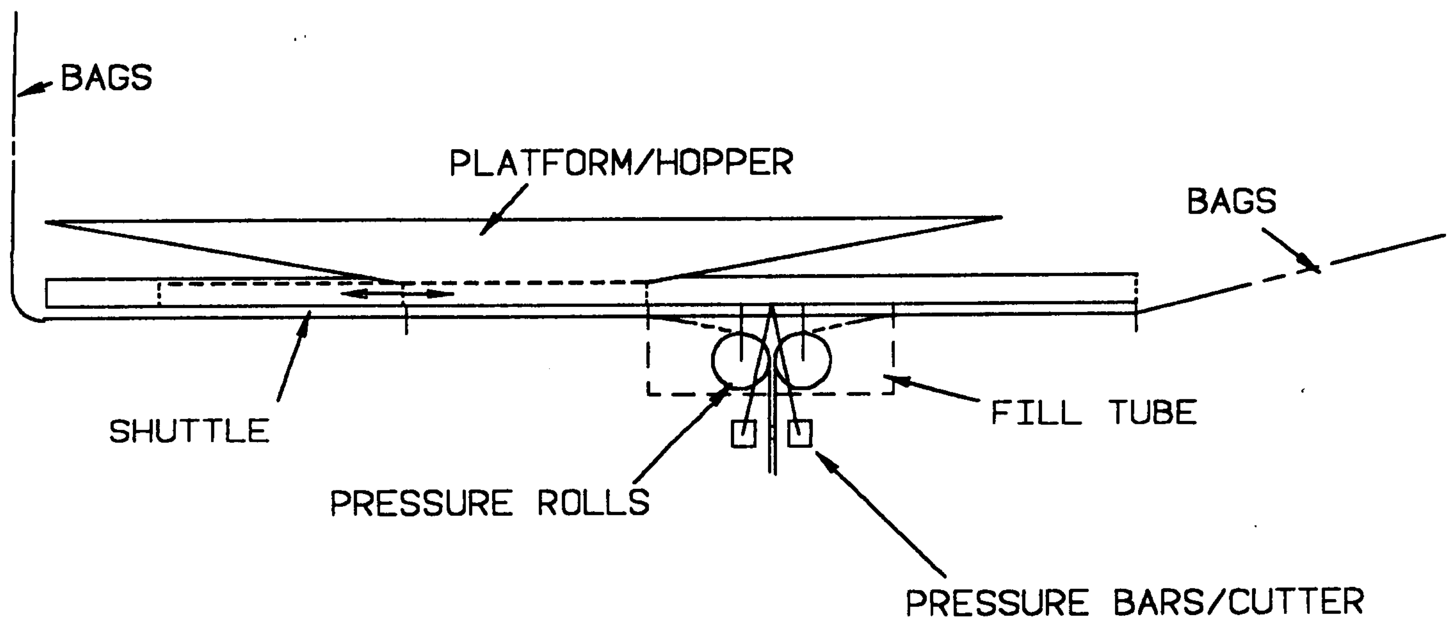

7.00
1.00
.75
3.81
.23
1.79
8.12
2.54
5.00
.75
1.79
8.00
2.50
10.00
GEORGIA INSTITUTE OF TECHNOLOGY
LUNAR SOIL BAGGING SYSTEM
ZIPLOC SEAL
CROSS SECTION
DWN 05/20/87 P.GLADNEY
CHK 05/26/87 J.CRESAP
SHT XX OF XX
$(\times 10^{-4} m)$

FIGURE

2



GEORGIA INSTITUTE OF TECHNOLOGY LUNAR SOIL BAGGING SYSTEM	
SHUTTLE TYPE METERING SYSTEM	
DWN 05/19/87 P.GLADNEY	CHK 05/20/87 D.WILDEY



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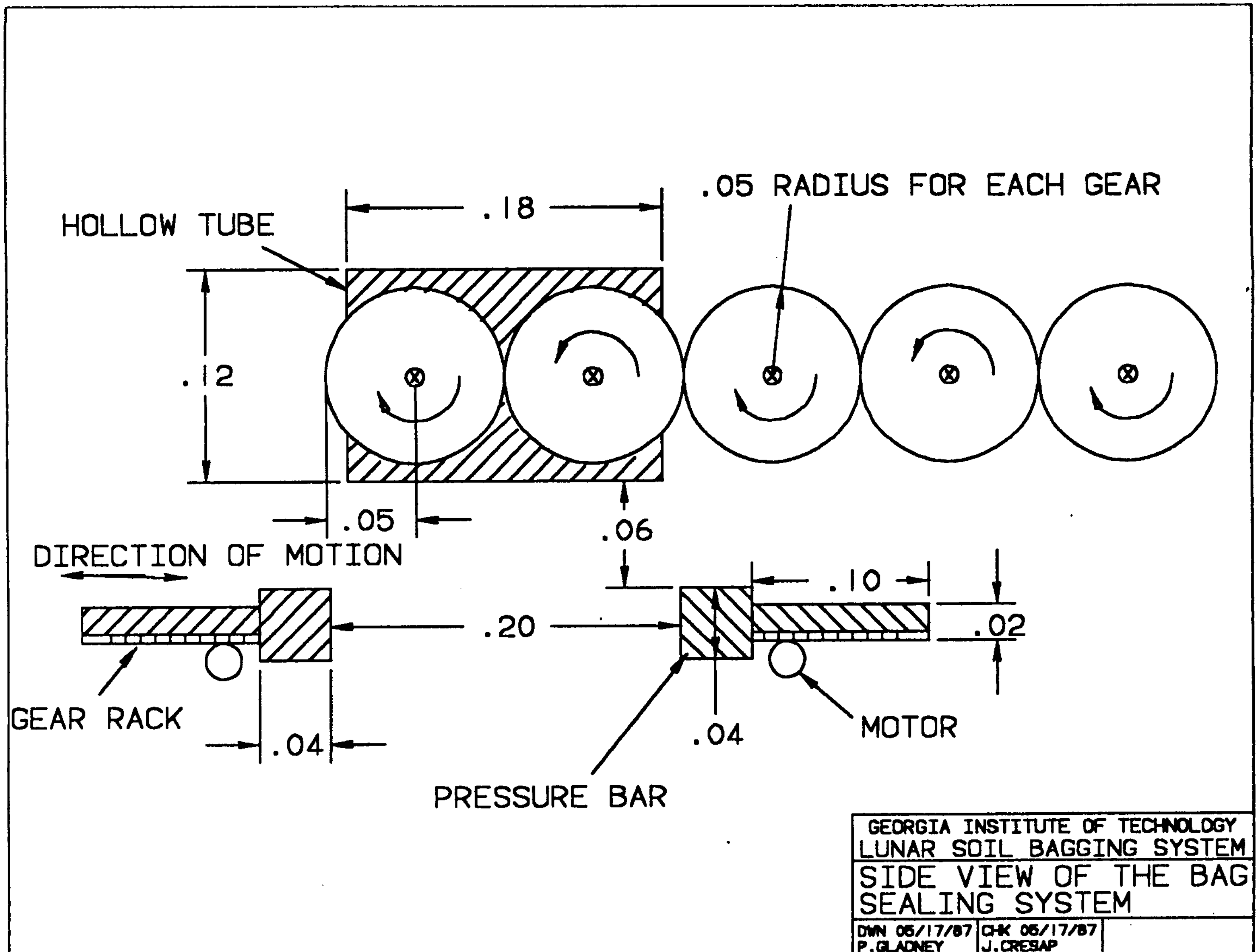
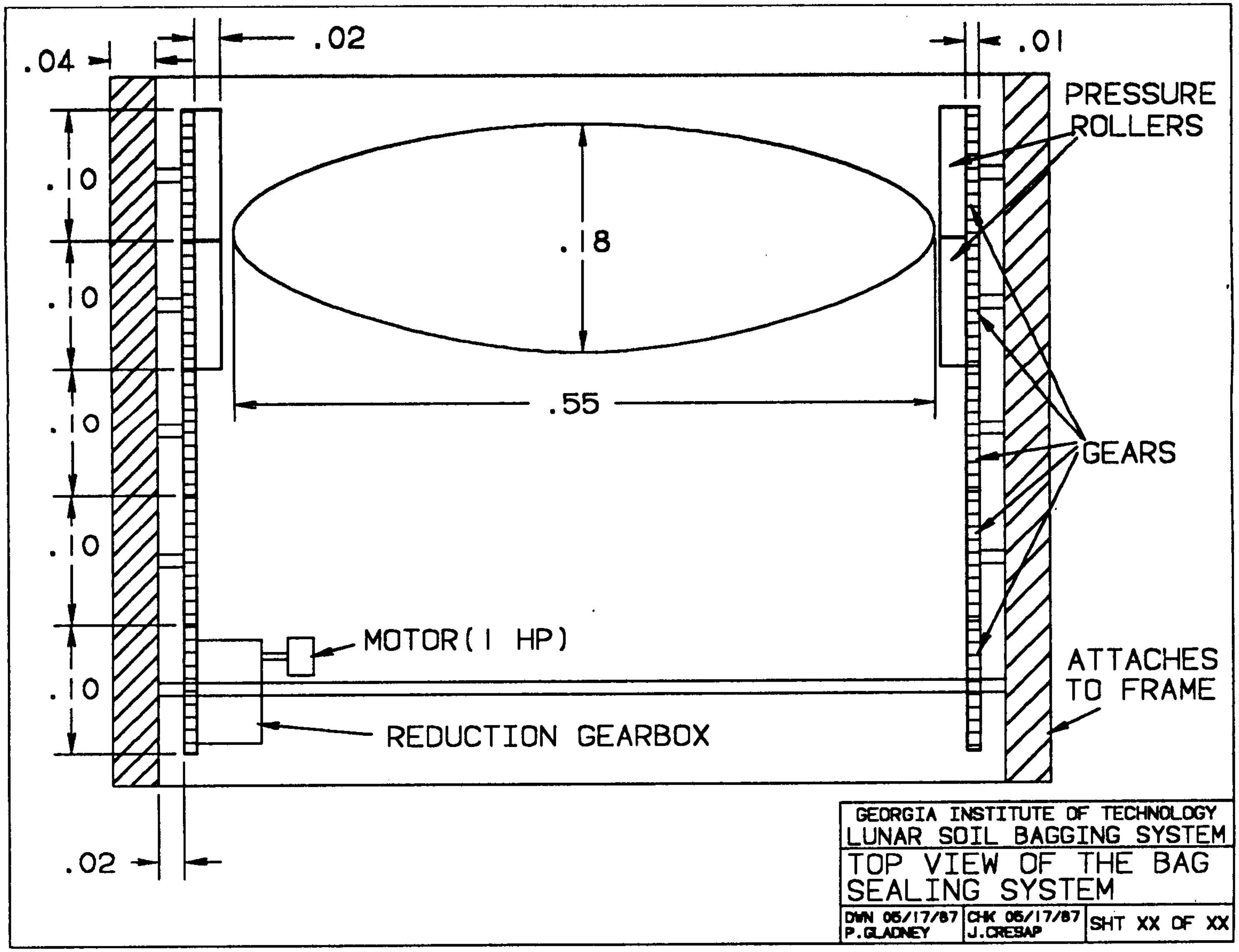
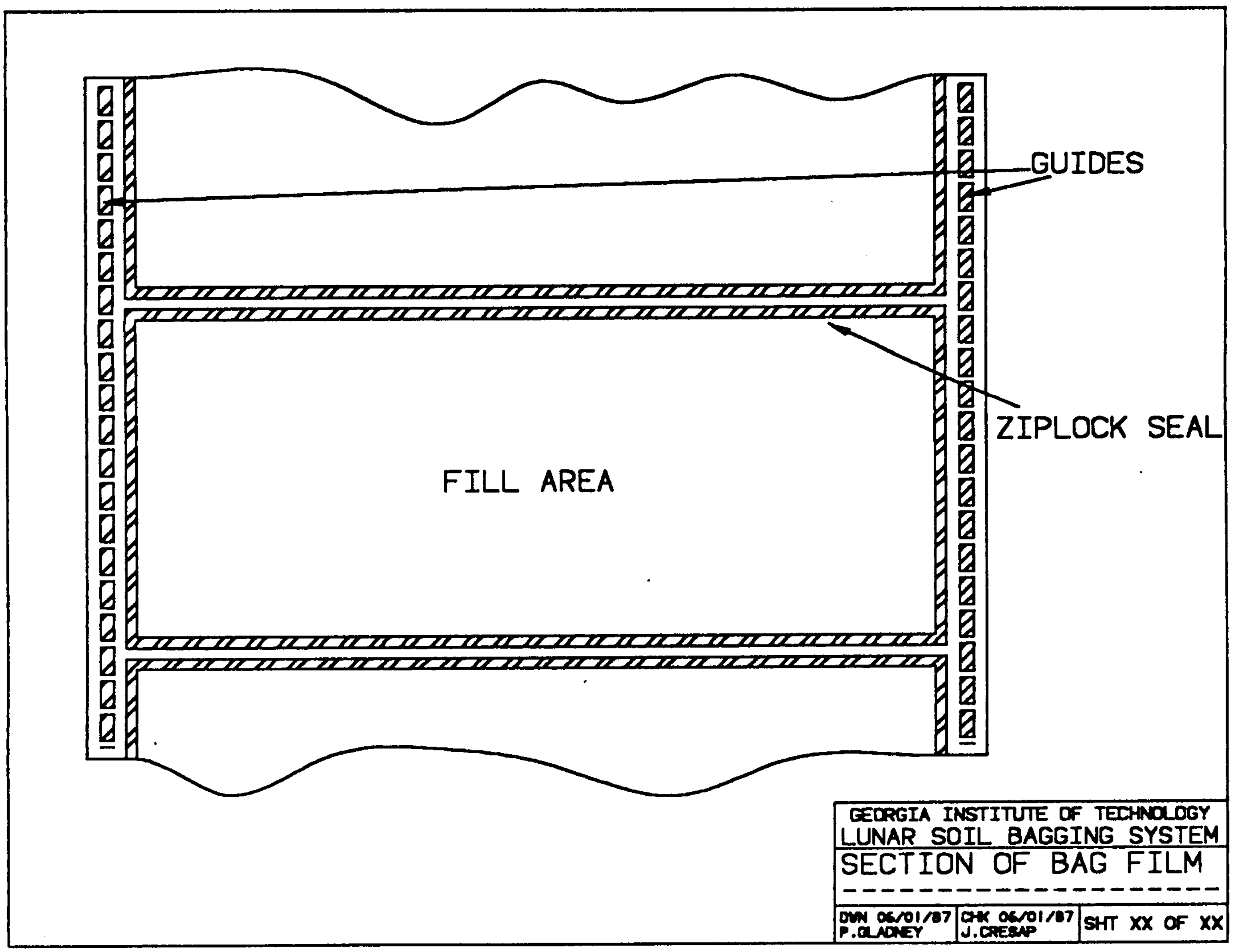
LUNAR SOIL BAGGING SYSTEM

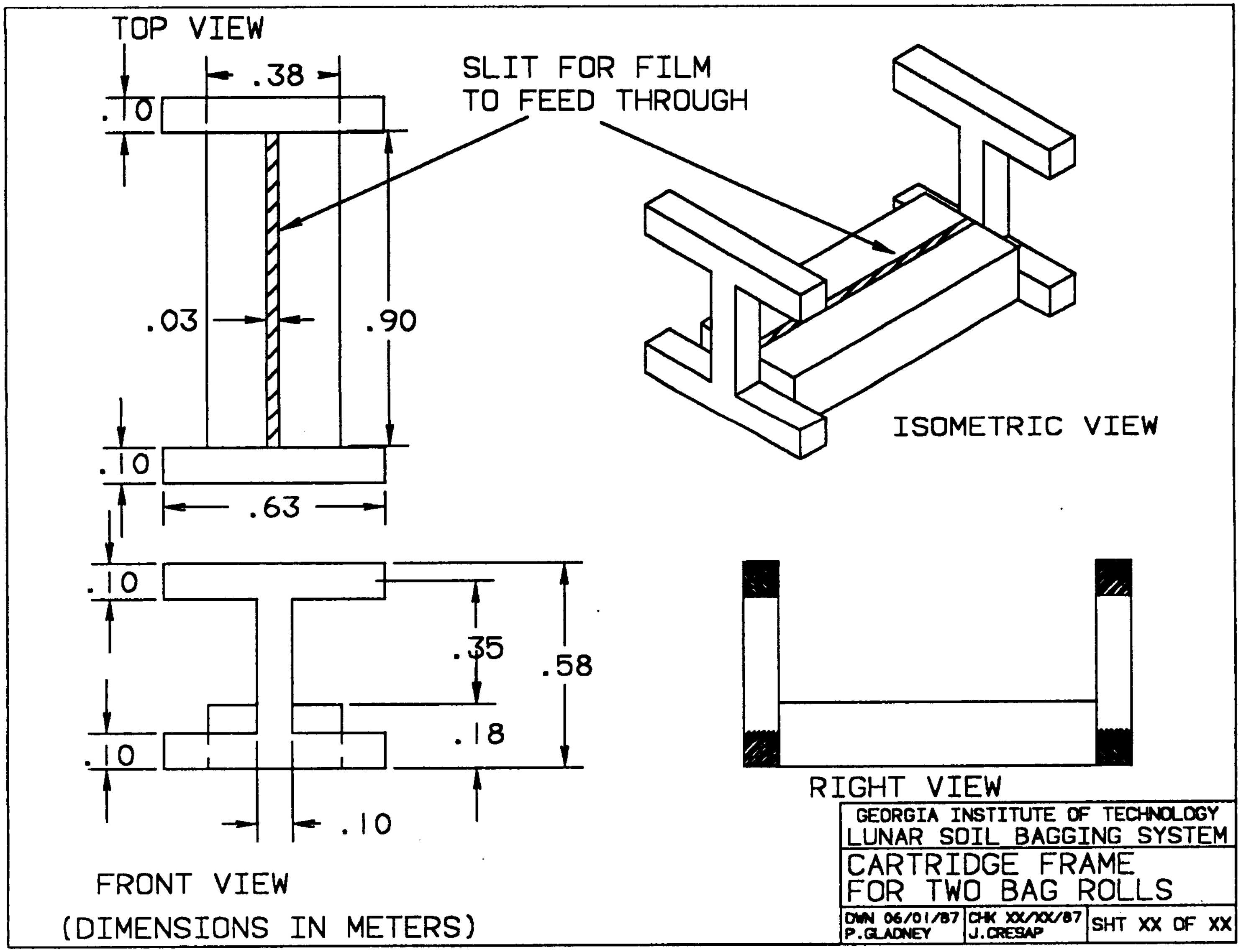
PLATFORM/BAGGER
(CONTINUOUS BAGGER)

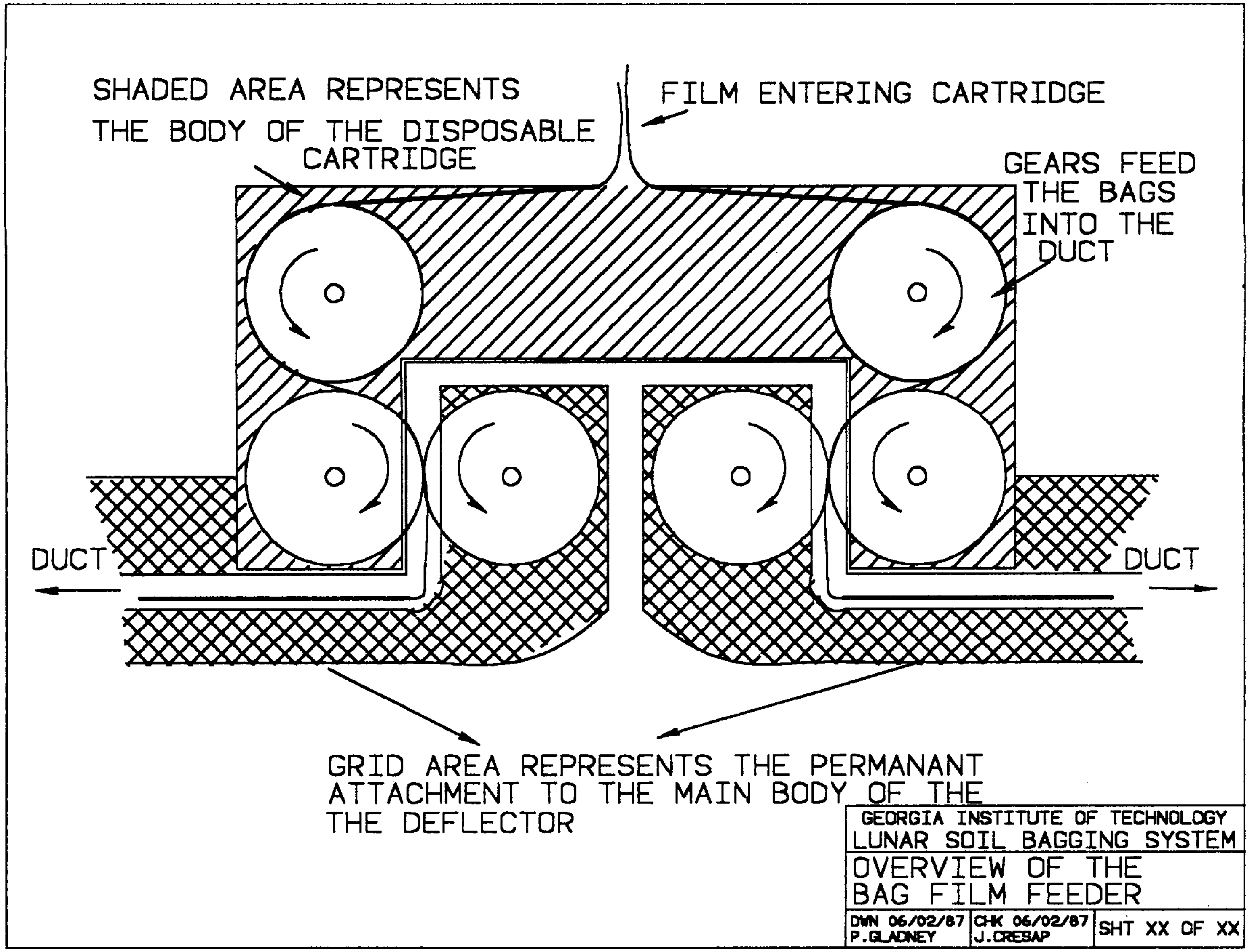
DWN 05/27/87 P.GLADNEY	CHK XX/XX/87 XXXX	SHT 01 OF XX


.18
HOLLOW TUBE
.05 RADIUS FOR EACH GEAR
.12
.05
.06
DIRECTION OF MOTION
.10
.20
.02
GEAR RACK
.04
.04
MOTOR
PRESSURE BAR
GEORGIA INSTITUTE OF TECHNOLOGY
LUNAR SOIL BAGGING SYSTEM
SIDE VIEW OF THE BAG SEALING SYSTEM
DWN 06/17/87 P.GLADNEY
CHK 06/17/87 J.CRESAP


.04
.02
.01
PRESSURE ROLLERS
.10
.10
.10
.10
.10
.18
.55
GEARS
MOTOR(1 HP)
REDUCTION GEARBOX
ATTACHES TO FRAME
.02
GEORGIA INSTITUTE OF TECHNOLOGY
LUNAR SOIL BAGGING SYSTEM
TOP VIEW OF THE BAG SEALING SYSTEM
DWN 06/17/87 P.GLADNEY
CHK 06/17/87 J.CRESAP
SHT XX OF XX


GUIDES
ZIPLOCK SEAL
FILL AREA
GEORGIA INSTITUTE OF TECHNOLOGY
LUNAR SOIL BAGGING SYSTEM
SECTION OF BAG FILM
DWN 06/01/87 P.GLADNEY
CHK 06/01/87 J.CRESAP
SHT XX OF XX


TOP VIEW
.38
.10
SLIT FOR FILM
TO FEED THROUGH
.03
.90
.10
.63
.10
.35
.58
.18
.10
.10
FRONT VIEW
(DIMENSIONS IN METERS)
ISOMETRIC VIEW
RIGHT VIEW
GEORGIA INSTITUTE OF TECHNOLOGY
LUNAR SOIL BAGGING SYSTEM
CARTRIDGE FRAME
FOR TWO BAG ROLLS
DWN 06/01/87
P.GLADNEY
CHK XX/XX/87
J.CRESAP
SHT XX OF XX


SHADED AREA REPRESENTS
THE BODY OF THE DISPOSABLE
CARTRIDGE
FILM ENTERING CARTRIDGE
GEARS FEED
THE BAGS
INTO THE
DUCT
DUCT
DUCT
GRID AREA REPRESENTS THE PERMANANT
ATTACHMENT TO THE MAIN BODY OF THE
THE DEFLECTOR
GEORGIA INSTITUTE OF TECHNOLOGY
LUNAR SOIL BAGGING SYSTEM
OVERVIEW OF THE
BAG FILM FEEDER
DWN 06/02/87
P.GLADNEY
CHK 06/02/87
J.CRESAP
SHT XX OF XX

CONTROLS

The lunar soil bagging implement will use television cameras to map the area for collection. Torque sensors are used to insure against developing a torque that could damage the skitter. Velocity controllers to control the angular speed of the brushes as well the velocity of the booms. Radiation sensors to determine the amount of soil that has been collected.

Two television cameras are mounted between each boom. As the booms are extended a contour map of the surface is created before the brushes begin to pitch the soil. Once the brushes begin operation, the optical sensing devises are of little or no use due to interference.

Once the optics are no longer useful, torque sensors are used to detect any abnormal forces during the sweep. This is particularly important after the brushes are in operation. If the torque sensors detect an abnormal torque both brushes are lifted off the lunar surface and over any object that is in the path of the brush.

Velocity controls are used to adjust the angular speed of each brush. As the distance from the brush to the hopper changes, the angular speed also changes.

Radiation sensors are used to determine the amount of soil that is in the hopper. Two radiation sensors are used, one in the bottom of the hopper the other above the hopper. The radiation sensor that is above the hopper is aimed at the hopper. The difference in readings between the two sensors determines the amount of soil that is in the hopper.

MOTORS

The motors used in the Lunar Soil Bagging System are the brushless DC type. Since fuel cells provide DC current, if one uses DC motors, no conversion of current is necessary, eliminating extra equipment. Also, usage of direct current allows for pulse width modulation for motor control. Brushless motors are used since they are more easily cooled than motors with brushes. This is because the majority of the heat generated in electric motors comes from resistance losses in the windings. A conventional motor has windings on both the rotor and stator. The stator can be cooled by incorporating refrigerant lines in the motor casing, but the rotor can conduct heat only through its bearings. In the brushless motor, the rotor is a permanent magnet and does not require special measures for cooling.

Extrapolating from a motor used in the Space Shuttle (17 horsepower AC synchronous motor weighing 17 pounds made by Delco Electronics) one determines that a motor will weigh 1 pound per horsepower. The aforementioned motor uses samerium-cobalt magnets to minimize size and weight. It has a non-metallic sleeve fitted into the stator bore for liquid cooling.

MATERIALS

Structural Materials:

The selection of structural materials was based on the following criteria:

1. Design properties must be maintained under worst case lunar conditions.
2. Materials must be light weight to reduce shipping costs.
3. Exposed parts must be wear resistant to withstand continuous sandblasting and friction between moving parts.
4. Material failure must be kept low since repairs on the moon are costly and the system is to be unmanned.

For high stress and high wear parts, Ti-6A1-4v was determined to be the best material. This titanium alloy was used for the structural members of the boom, the ramps leading to the platform, the housing for the metering shuttle, and the tips of the brushes. This alloy has a high strength-to-weight ratio and high wear resistance. Ti-6A1-4v is commonly used in aircraft and marine vessels.

Since most lubricants used on Earth would vaporize on the moon, moving parts should be made of wear resistant materials. Teflon coatings on joints would reduce friction wear. Solid lubricants such as graphite can be used in closed areas.

To reduce weight, composites weighing one-fifth as much as steel were used where high strength and wear resistance were not as critical. Kevlar 29, an aramid composite, was used to make cables for the brushes. These cables allow the necessary amount of flexibility. ASA/3501-6, a carbon/epoxy composite, was used for more rigid parts such as the deflection shield and the platform. Both composites have two-thirds the strength of steel and are less dense.

Bag Materials:

The material for the bag needs to be flexible and strong. The lunar environment tends to degrade most polymers. An exception was the family of fluorocarbon based polymers. Teflon, or polytetrafluoroethylene, was such a polymer and was chosen for its overall strength and temperature properties. Filling the Teflon with 15% carbon fibers more than doubled the strength of the plastic at the higher temperatures (above 66 C). Tensile strengths of the filled Teflon ranged from 5.5 MPa at -184 C to about 41 MPa at 149 C.

The polymer was made into 5 mills (127 um) thick film. To seal each bag tightly, two sheets of film would be pressed together. The male part of a mechanical "zip-lock" would be included on one sheet and the female part on the other sheet. This method of pressing and sealing made it possible to have a continuous bagging system (see Figure 6).

STRUCTURAL MATERIAL PROPEERTIES

Ti-6Al-4V	Titaniium alloy for brush tips, ramp		
	Tensile yield strength		689 MPa at -185 C
			661 MPa at 149 C
		Density	4.51 g/cm^3
			4510 kg/m^3
ASA/3501-6	Carbon/epoxy composite for shields, platform/truss or boom elements		
	Tensile yield strength		276 MPa
		Density	1.4 g/cm^3
			1400 kg/m^3
KEVLAR 29	Aramid composite. Fro brush bristles		
	Tensile yield strength		276 MPa
		Density	1.44 g/cm^3
			1440 kg/m^3
BRONZE	Zinc-copper alloy. Used for soil shuttle.		
	Tensile yield strength		241 MPa
		Density	8.5 g/cm^3
			8500 kg/m^3
TEFLON	Polytera-fluoraethylene, 5% carbon filled. Used for the bags.		
	Tensile yield strength		40.7 MPa at -183 C
			5.51 MPa at 149 C
		Density	4.51 g/cm^3
			4510 kg/m^3
		Elongation	2 % at -183 C

Joints can be coated with teflon to reduce friction or graphite can be used as a dry lubricant in "enclosed" areas.

COF teflon = 0.04

POWER SUPPLY

The Lunar Soil Bagging System uses hydrogen/oxygen fuel cells as a power supply. A fuel cell consists of a fuel (in this case hydrogen), an oxidant (oxygen) and two electrodes in contact with the electrolyte (potassium hydroxide, for instance). One electrode, the anode, is in contact with the fuel. The cathode is in contact with the oxidant. Electrons released from the hydrogen pass from the electrode through the load to the cathode. The electrolyte conducts the newly formed hydrogen ion to the cathode side where it combines with the oxygen and the free electrons to form water.

Approximately one-half of the water formed is consumed in the reaction. The other half constitutes a by-product and must be removed to avoid diluting the electrolyte. This waste water can be used as a heat sink in the cooling system of the bagger. When the bagger is refueled, the water can be removed from its storage tank and separated back into hydrogen and oxygen to be used again in the fuel cell.

Hydrogen/oxygen fuel cells are not the only type. There are other fuels and oxidants available, but there are several factors which make them less desirable. Hydrogen/oxygen fuel cells are more efficient than other fuel cells. The product of the electrochemical reaction in the cell is water which may be used in cooling and can be recycled into fuel and oxidant to be used again. Also, since hydrogen and oxygen are present on the moon, it would be possible to obtain fuel for the cells on the moon instead of having to ship it from the earth.

Compared with other sources of energy, fuel cells have several advantages. Fuel cells are more efficient than thermochemical devices and have no moving parts. Fuel cells perform a direct, one-step conversion of chemical energy into electricity. Although heat is given off in the process, it does not constitute an essential link in the energy conversion chain. Compared with batteries, fuel cells have a higher energy density when power is needed over an extended period of time. Fuel cells can be refueled by resupplying the fuel and oxidant sources, and can be modularly assembled for ease of service and replacement.

Using the fuel cells on the Space Shuttle as a guide, one may expect hydrogen/oxygen fuel cells to have a power output of 5 kilowatts, a specific weight of 13.6 kilograms per kilowatt, and a specific volume of 0.034 cubic meters per kilowatt. The lifetime of these cells is in the thousands of hours. Therefore, for the 25 kilowatt plant of the bagger, there is a weight of 556 newtons and a volume of 0.85 cubic meters.

CONCLUSION

The Lunar Soil Bagging System is a feasible scheme for collecting and bagging regolith. The rotating brush design eliminates the need for separately filtering the soil before it is bagged. The bags from the continuous bagging system are tightly sealed and provide uniformly dense packages. The bags are designed to facilitate being lifted. Furthermore, the material used provides flexibility and strength. The overall system is fully automated and produces a minimum of four bags of soil per minute. This rate is sufficient for producing bags of soil to protect a lunar module.

RECOMMENDATIONS

This design utilizes two vertical rotating brushes to collect soil. Another alternative considered was to involve electrostatics in the collection. There seems to be some promise for this approach but information is limited and further research is be needed in this area.

Another version of the brusher system would be to have the brushes lie horizontally and use centrifugal force to collect soil. However, efficiency and cotrol present several limitations with this method.

The closing system used for the bag was a mechanical "zip-lock". Two other possible mechanical type closures considered are valve type closures and clamps. If an adhesive could be developed that would not be volatile in the vacuum, it could be used to make a simpler seal.

ACKKNOWLEDGEMENTS

The members of the Lunar Soil Bagging Implement Group would like to express their appreciation to the following:

Mr. J.W. Brazell
Dr. H.L. Johnson
The Torrington Company
The Timken Company

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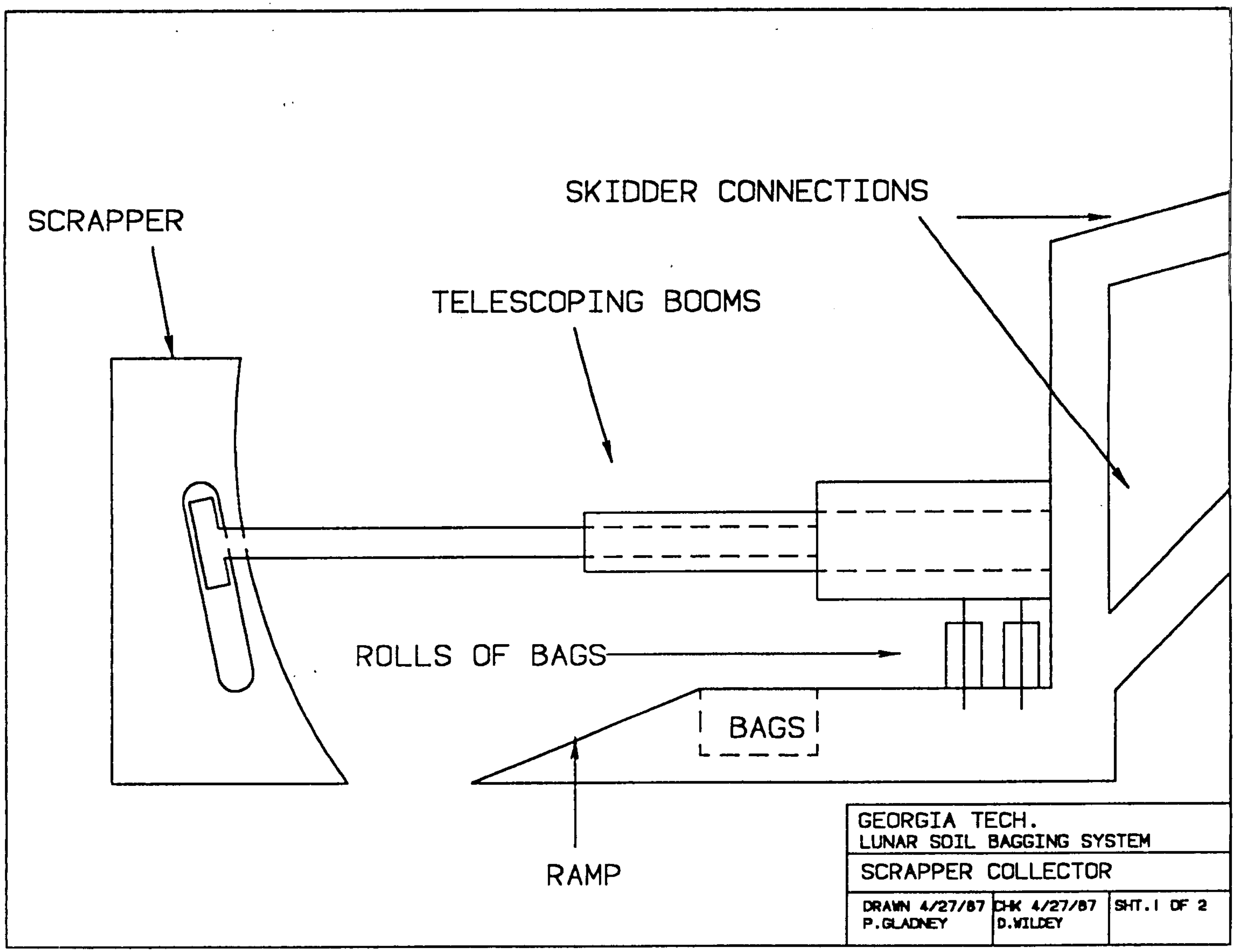
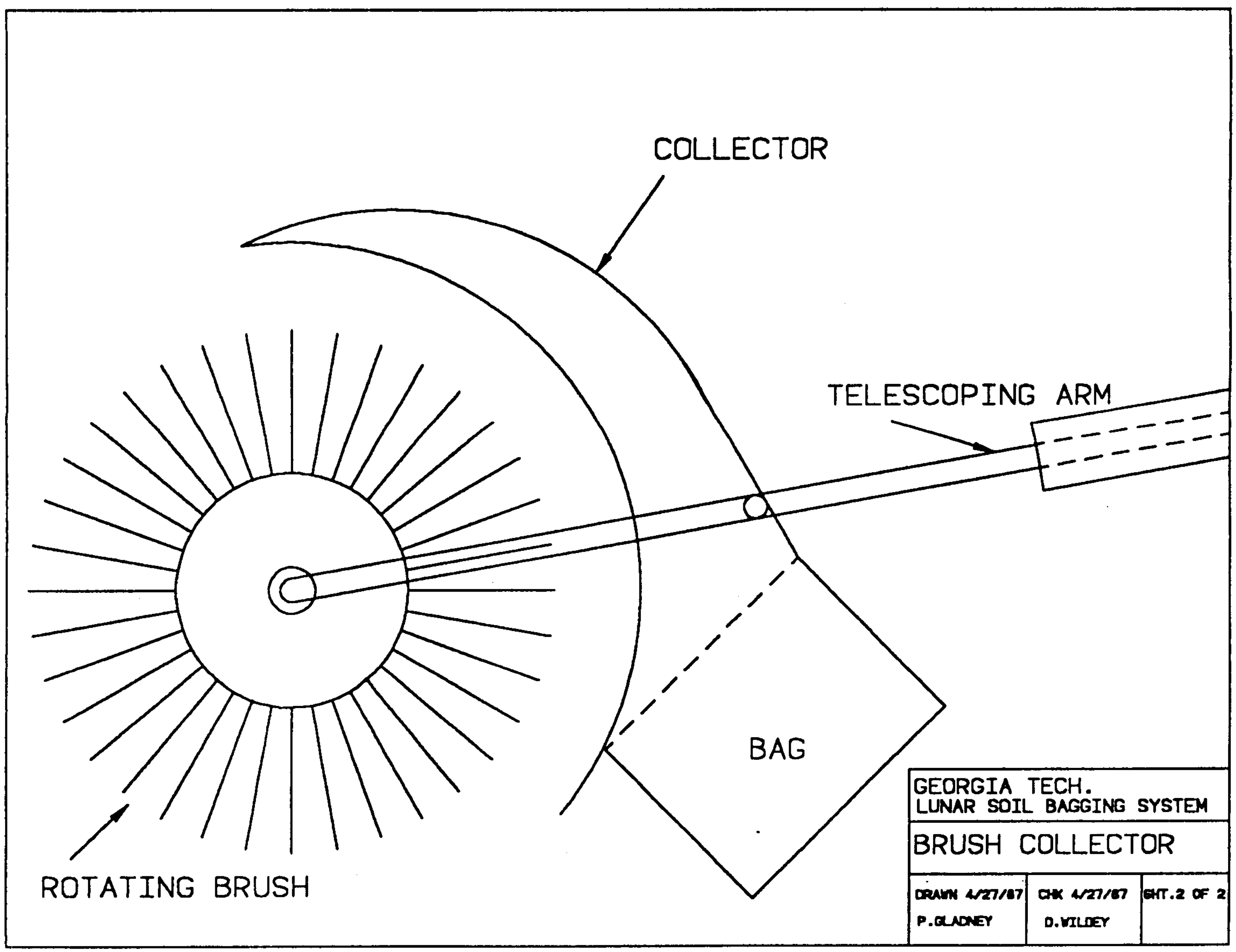
APPENDICES

A. Alternative designs

B. Calculations

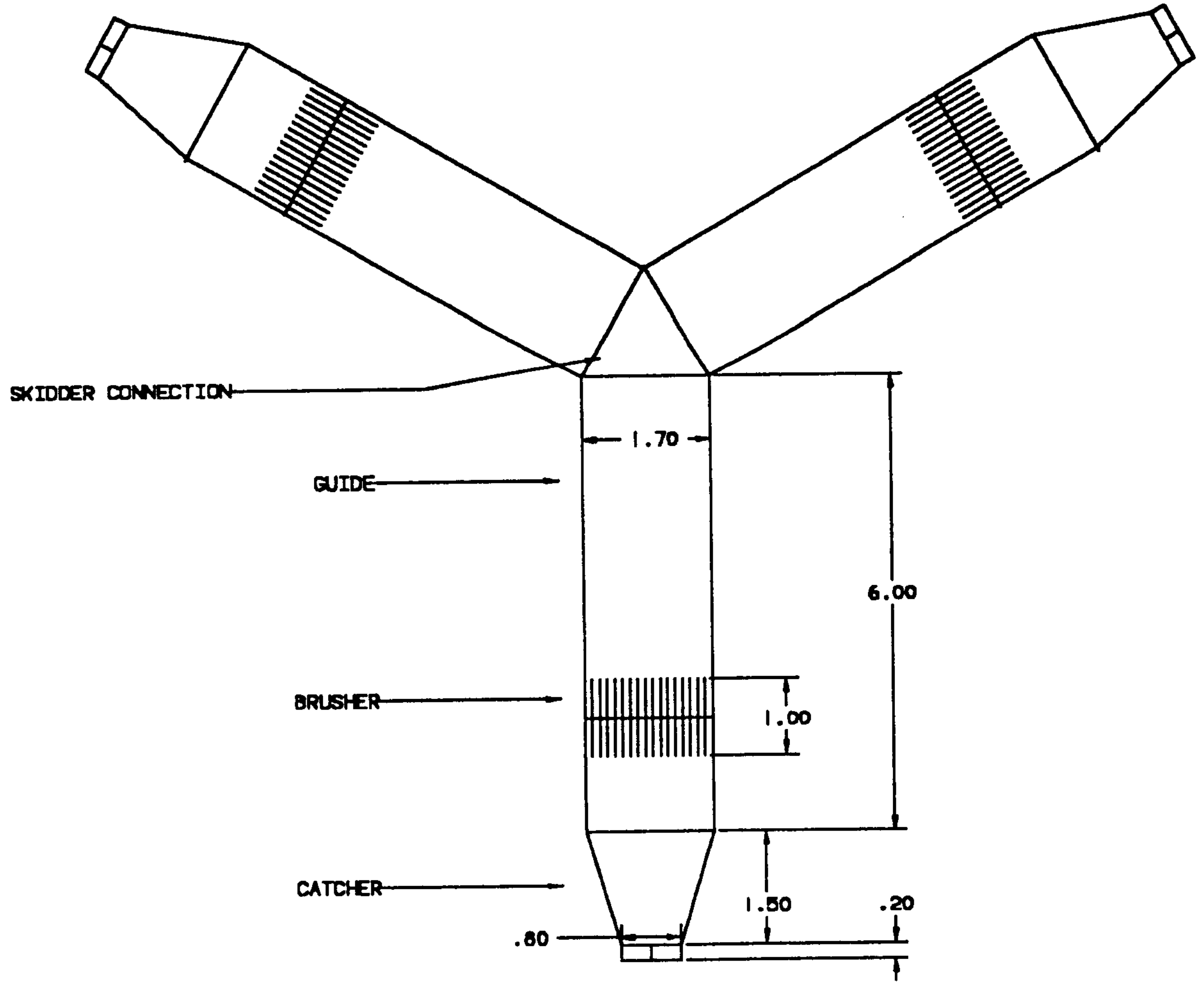
C. Status reports


SCRAPPER
TELESCOPING BOOMS
SKIDDER CONNECTIONS
ROLLS OF BAGS
BAGS
RAMP
GEORGIA TECH.
LUNAR SOIL BAGGING SYSTEM
SCRAPPER COLLECTOR
DRAWN 4/27/87
P.GLADNEY
CHK 4/27/87
D.WILDEY
SHT.1 OF 2


COLLECTOR
TELESCOPING ARM
BAG
ROTATING BRUSH
GEORGIA TECH.
LUNAR SOIL BAGGING SYSTEM
BRUSH COLLECTOR
DRAWN 4/27/87
P.GLADNEY
CHK 4/27/87
D.WILDEY
SHT.2 OF 2

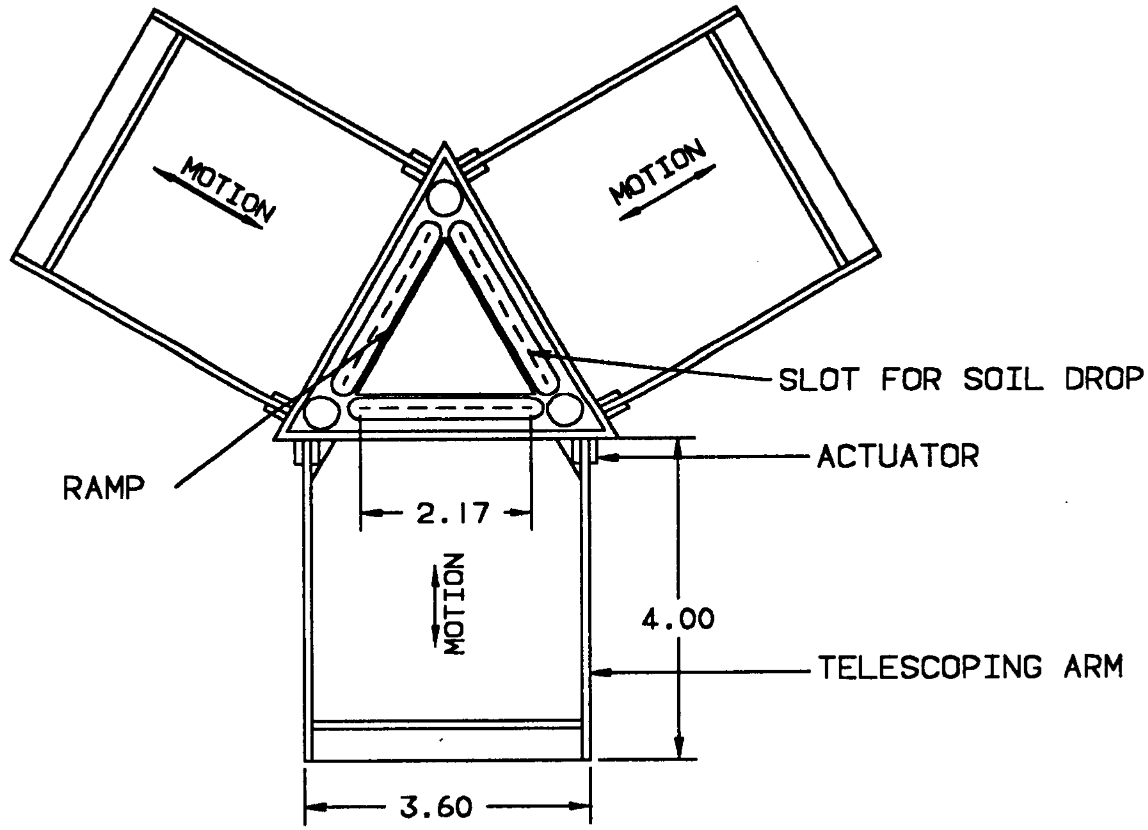
3-BRUSHER SYSTEM

(ALL THREE LEGS HAVE SAME DIMENSIONS)



SOIL SCRAPPER AND BAGGER

(ALL DIMENSIONS ARE IN METERS)

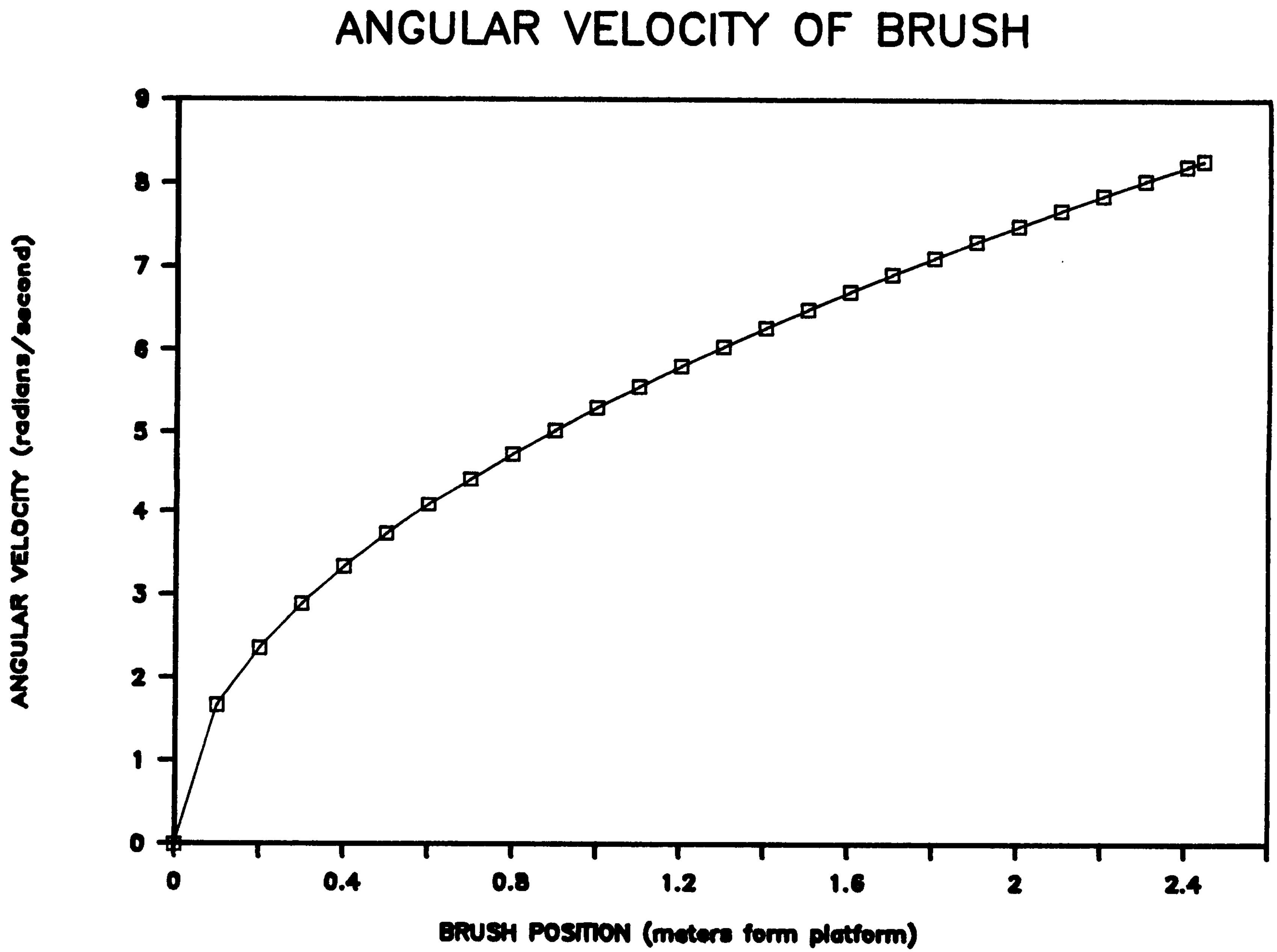


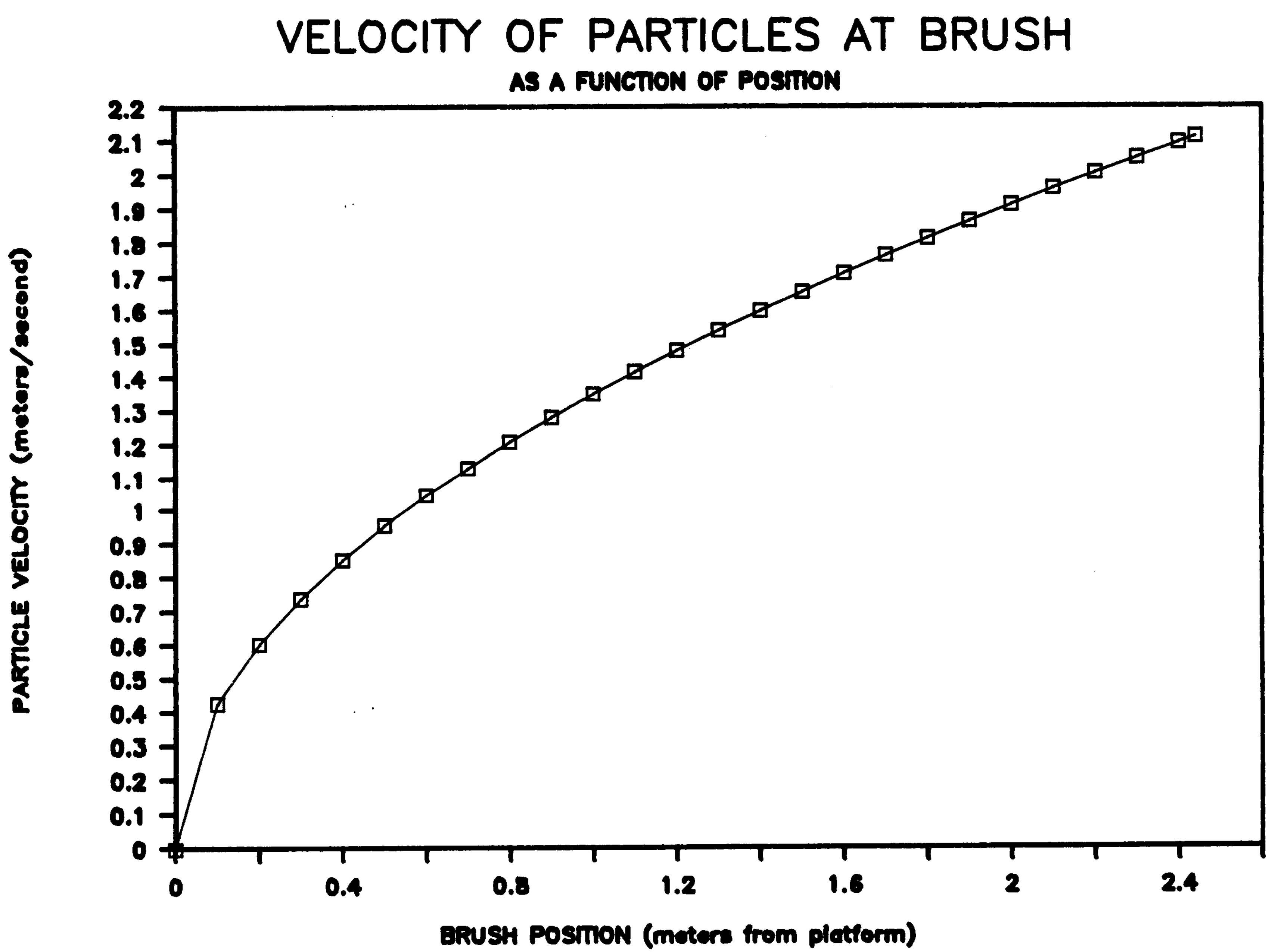
GROUP 5-LUNAR SOIL BAGGER
DRAWN BY: PATRICIA E. GLADNEY
DATE: APRIL 22,1987

ANGULAR VELOCITY OF BRUSH AS A FUNCTION OF POSITION

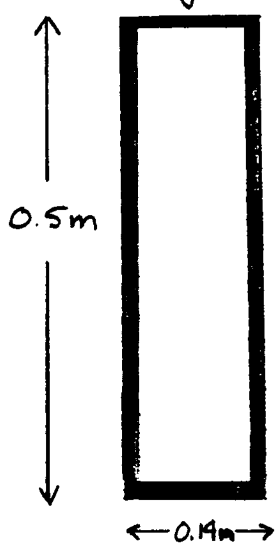
ACC. DUE TO GRAVITY	1.635	m/s^2
ANGLE OF PITCH	45	DEGREES

POSITION m	PARTICLE VELOCITY m/s	ANGULAR VELOCITY rad/sec
0.00	0.00	0.0000
0.10	0.43	1.6771
0.20	0.60	2.3717
0.30	0.74	2.9048
0.40	0.86	3.3541
0.50	0.96	3.7500
0.60	1.05	4.1080
0.70	1.13	4.4371
0.80	1.21	4.7435
0.90	1.28	5.0312
1.00	1.35	5.3034
1.10	1.42	5.5622
1.20	1.48	5.8095
1.30	1.54	6.0468
1.40	1.60	6.2750
1.50	1.66	6.4953
1.60	1.71	6.7083
1.70	1.76	6.9147
1.80	1.81	7.1152
1.90	1.86	7.3102
2.00	1.91	7.5001
2.10	1.96	7.6853
2.20	2.01	7.8661
2.30	2.05	8.0429
2.40	2.10	8.2159
2.44	2.11	8.2841


ANGULAR VELOCITY OF BRUSH
ANGULAR VELOCITY (radians/second)
0
1
2
3
4
5
6
7
8
9
0
0.4
0.8
1.2
1.6
2
2.4
BRUSH POSITION (meters form platform)


VELOCITY OF PARTICLES AT BRUSH
AS A FUNCTION OF POSITION
PARTICLE VELOCITY (meters/second)
2.2
2.1
2
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.4
0.8
1.2
1.6
2
2.4
BRUSH POSITION (meters from platform)

Beam Housing



not to scale

material thickness = 0.01 m
area = $(0.5m)(0.14m) - (0.48m)(0.12m) = 0.0124\,m^2$
length = 1.83m
Volume = $(0.0124m^2)(1.83m) = 22.7 \times 10^{-3}\,m^3$
material - Al 4032-T6 : $\rho = 2.7\,g/cm^3 = 2700\,Kg/m^3$
Therefore,

$$\text{Mass} = \rho V = (2700\,Kg/m^3)(22.7 \times 10^{-3}\,m^3) = 61.3\,Kg$$

$$\text{Weight (on Moon)} = 61.3\,Kg \times \frac{9.81\,m/s^2}{6} = 100\,N \quad (22.5\,lb_f)$$

Angular Motion System

Pulleys

shafts :

large : area/shaft = $\frac{\pi(0.300m)^2}{4} = 70.7 \times 10^{-3}\,m^2$, length = 1.63m $\Big\}$ $V = 115 \times 10^{-3}\,m^3$

small : area/shaft = $\frac{\pi(0.070m)^2}{4} = 3.85 \times 10^{-3}\,m^2$, length = 0.085m $\Big\}$ $V = 327 \times 10^{-6}\,m^3$

wheels:

small : area/wheel = $61.6 \times 10^{-3}\,m^2$, thickness = 0.07m $\Big\}$ $V = 4.31 \times 10^{-3}\,m^3$

large : area/wheel = $0.785\,m^2$, thickness = 0.07m $\Big\}$ $V = 55.0 \times 10^{-3}\,m^3$

material - ASA/3501-6 : $\rho = 1400\,Kg/m^3$

need 2 large, 4 small shafts; 4 small, 2 large wheels

$$V_{Total} = 2(115 \times 10^{-3}\,m^3) + 4(327 \times 10^{-6}\,m^3) + 4(4.31 \times 10^{-3}\,m^3) + 2(55.0 \times 10^{-3}\,m^3)$$
$$= 359 \times 10^{-3}\,m^3$$

$$\text{Mass} = \rho V = (1400\,Kg/m^3)(359 \times 10^{-3}\,m^3) = 503\,Kg$$

$$\text{Weight (on Moon)} = 503\,Kg \times \frac{9.81\,m/s^2}{6} = 822\,N \quad (185\,lb_f)$$

Kevlar 29 cable :

length/set = 6.15 m x 2 sets = 12.3 m

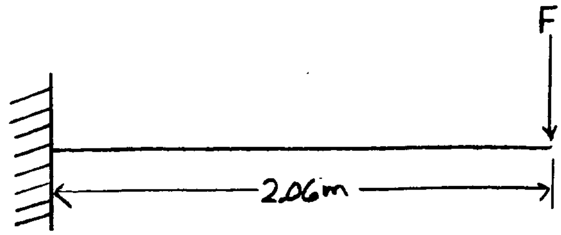
$$\text{area} = \frac{\pi(0.04\,m)^2}{4} = 1.26\times10^{-3}\,m^2$$

$$Vol = 15.5\times10^{-3}\,m^3$$

$$Mass = \rho V = (1440\,kg/m^3)(15.5\times10^{-3}\,m^3) = 22.3\,kg$$

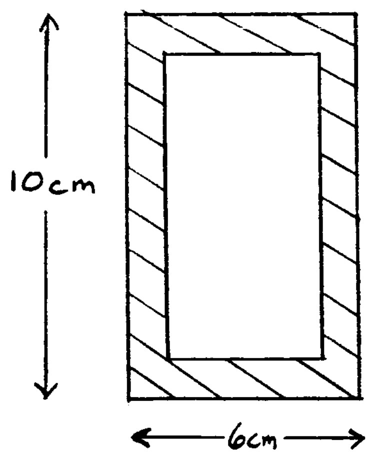
Weight (on Moon) = 36.5 N (8.21 lb_f)

Thus, angular motion system weighs 859 N (193 lb_f)



Material: Alpha-Beta Titanium
(6% Al, 6% V, 2% Sn)
$S_y = 150{,}000$ psi

Maximum shear occurs at the center of the beam.
Using a rectangular cross-section as shown:



material thickness = 1 cm

Area of material $= (10cm)(6cm) - (8cm)(4cm)$

$$= 28cm^2 \times \left(\frac{1in}{2.54cm}\right)^2 = 4.34\ in^2$$

$$= 28cm^2 \times \left(\frac{m}{100cm}\right)^2 = 2.8 \times 10^{-3}\ m^2$$

Static Design

$$\tau_{max}\Big|_{\text{rectangular section}} = \frac{3V}{2A} \quad ; \quad S_{sy}\ (\text{yield strength in shear}) = \frac{S_y}{2}$$

$$\therefore\ S_{sy} = 75{,}000\ psi$$

Thus, using maximum shear-stress theory, for safety:

$$\frac{3V}{2A} < 75{,}000\ psi \quad \text{or} \quad V_{max} < 217{,}000\ lb_f$$

If a factor of safety of $n = 2$ is used,

$$V_{max}\Big|_{n=2} = \frac{V_{max}}{2} < 108{,}500\ lb_f \simeq 483\ KN$$

Fatigue Design

$S_e' = 579$ MPa (for R50001-series Titanium alloys)

$$S_e \triangleq K_a K_b K_c K_d K_e S_e'$$

$K_a = 1$ (polished)
K_b:

$$0.95A = 0.05hb = 0.05(28cm^2) = 1.4cm^2$$

$$1.4cm^2 = 0.0766d^2 \Rightarrow d = 4.275 cm \Rightarrow K_b = 0.826$$

K_c: 99% reliability $\Rightarrow K_c = 0.814$

K_d: Maximum temperature = 250°F $\Rightarrow K_d = 1$

$K_e = 1$

Therefore,

$$S_e = (1)(0.826)(0.814)(1)(1)579 \text{ MPa} \doteq 389 \text{ MPa}$$

Thus,

$$\frac{3V}{2A} < 389 \text{ MPa} \Rightarrow V\Big|_{max} < 726 \text{ KN}$$

If a factor of safety of 2 is used,

$$V_{max}\Big|_{n=2} = \frac{V|_{max}}{2} < 363 \text{KN} \quad (81{,}600 \text{ lb}_f)$$

Titanium

$\rho = 4.51 g/cm^3$, $A = 2.8\times10^{-3} m^2$, total length (including what is always supported) = 1.65 m $\Rightarrow V = (2.8\times10^{-3} m^2)(2.06 m) = 5.77\times10^{-3} m^3 \times \left(\frac{100cm}{m}\right)^3$

Therefore, $V = 5.77\times10^3 cm^3$

Mass = $\rho V = (4.51 g/cm^3)(5.77\times10^3 cm^3) = 26.0$ Kg

Weight (on Earth) = $26.0 Kg \times 9.81 m/s^2 = 255 N$ ($57.4 lb_f$)

Weight (on Moon) = $26.0 Kg \times \frac{9.81 m/s^2}{6} = 42.5 N$ ($9.56 lb_f$)

$\tau_{soil} = 411.8 \, KN/m^2$ Radius of brush $= 0.255 m$
width of brush $= 1.22 m$
bristle diameter $= 1 mm = 10^{-3} m$
162 rows of bristles ; $\approx$ 1cm between bristles

# of bristles per row is x

$$1.22m - x(0.001m) - (x-2)(0.01m) = 0$$
$x = 112.7$ bristles, therefore use 113 bristles

Thus, we have (162 rows)(113 bristles/row) = 18,306 bristles

area of bristles/row $= (113)\left(\frac{\pi (10^{-3})^2}{4}\right) = 88.8 \times 10^{-6} m^2$

force/row to shear soil = area/row x shear stress of soil
$= (88.8 \times 10^{-6} m^2)(411.8 \, KN/m^2)$
$= 36.6 \, N/row$

≈ 20.5 rows will be in contact with the soil at any one time
$\therefore$ force to shear soil $= (36.6 \, N/row)(20.5 \, rows)$
$= 750 N$

Torque = force x radius $= (750N)(0.255m) = 191 \, N \cdot m$

Power $= \dfrac{2\pi n T}{60(10)^3}$ $\quad n|_{max} = 75 \, rpm$

Power $= \dfrac{2\pi (75 \, rev/min)(191 \, N \cdot m)}{(60 \, sec/min)} = 1.5 \, KW$ (2 hp)

Moment arm = 2.93m

Assuming a worst case scenario of all the weight positioned at the end of the arm:

Total force at end of the arm = 100N (Housing) + 42.5 N (Beam) + 42 N (Brush) = 185N

Torque = (force)(moment arm) = (185N)(2.93 m) = 542 N·m

Desire an angular velocity of the rotating boom of 0.0296 rad/sec. (We desire to move the arm and brush through an arc of 81.4 degrees in 48 seconds).

Therefore,

$P = (542 N{\cdot}m)(0.0296\ rad/sec) = 16.0\ W$ for one arm.

But the bagger uses one motor to drive 4 booms. So

$P_{total} = 4(16.0 W) = 64.0 W$ (0.0858 hp)

Brush Shaft

area $= \pi r^2 = \pi(0.035m)^2 = 3.85 \times 10^{-3}\ m^2$
length = 1.22m

Therefore, Volume $= (1.22m)(3.85 \times 10^{-3} m^2) = 4.70 \times 10^{-3}\ m^3$

Mass $= \rho V$; material - titanium (Ti-6AL-4V) : $\rho = 4510\ Kg/m^3$

Thus

$$\text{Mass} = (4.70 \times 10^{-3} m^3)(4510\ kg/m^3) = 21.2\ Kg$$

$$\text{Weight (on Moon)} = 21.2kg \times \frac{9.81m/s^2}{6} = 34.7N$$

Brush Bristles

area/bristle $= \pi(5.0 \times 10^{-4} m)^2 = 7.85 \times 10^{-7}\ m^2$
length = 0.22m

Therefore, volume/bristle $= (7.85 \times 10^{-7} m^2)(0.22m) = 1.73 \times 10^{-7}\ m^3$/bristle

$$18{,}306 \text{ bristles} \times 1.73 \times 10^{-7} \frac{m^3}{\text{bristle}} = 3.16 \times 10^{-3}\ m^3 = \text{Volume}$$

Material - Kevlar 29 : $\rho = 1440\ Kg/m^3$

$$\text{Mass} = \rho V = (1440\ kg/m^3)(3.16 \times 10^{-3} m^3) = 4.55\ Kg$$

$$\text{Weight (on Moon)} = 4.55 Kg \times \frac{9.81m/s^2}{6} = 7.45N$$

Total Brush Weight (on Moon) = 42.2N

Brush Motor

1 lb/hp x 2 hp = 2 lb (8.90N) ; motor box $= (0.029m^3)(1400Kg/m^3) = 40.6\ Kg$
material - ASA/3501-6
$$\text{Weight} = 40.6\ Kg \times \frac{9.81m/s^2}{6} = 66.4N$$

$$\text{System Weight} = 2(34.7N + 7.45N + 8.90N + 66.4N) = 235N$$

April 8, 1987 Week #1

MEMORANDUM

TO: Mr. Brazell

FROM: Group V: Adams, Anderson, Barrett, Cresap, Gladney, Wildey

SUBJECT: Weekly Progress Report

---

1. The group has chosen the title for the project:
<u>LUNAR SOIL BAGGING SYSTEM</u>

2. A tentative purpose for the project would read as follows: to design a machine to collect lunar regolith while attached to the underside of the walker and then load the soil into flexible containers. Further constraints upon the problem include that the system must withstand (1) cosmic radiation, (2) extreme temperature shifts (-250 to +200 degrees fahrenheit), (3) meteoroid bombardment (5km/sec to 20km/sec). Also the weight, size, and energy consumption of the system must be minimized while the strength should be maximized. The bags must be designed in such a way so that each square cm of the lunar base is covered by 700 g of regolith so that the inhabitants are protected from the radiation of solar flares. The time window for bag production is 18 months.

3. This week each member of the design team researched different aspects of the project in an attempt to eliminate unsatisfactory processing schemes. It was determined that a crusher or grinder would be dangerous, prone to failure, and would require too much energy. Flexible sand bagging material is available for the above conditions, but high temperature aging of the present materials reveals the need for further research. It was found that the lunar soil consists of mostly metals (Ti, Al, Fe, Mg), and the possibility of transporting large quantities of lunar soil by principles of electrostatics shows much potential (even though as of yet there is no current proof of this application). From previous ME 4182 report data it was found that it would not be practical to use hydraulic actuators for regolith collection.

4. The present most viable solution to the problem (see accompaning sketch) keeps the bag and regolith in the horizontal plane in an attempt to minimize energy expenditures. This system includes a stepper motor actuated regolith collection method, an electrostatic separation operation, a bag delivery system that utilizes replaceable cartridges of continuous bags, and a bag filling operation that includes an auger for delivery and a scale to insure proper bag density.

M.E. 4182

WEEKLY STATUS REPORT

MARCH 16, 1987

Project : Soil bagging system.

Individual Efforts:

1. David Wildey has determined some design parameters concerning the bag for containing the soil; these criteria are : (1) the bag must be tightly packed (possess little free volume) ; (2) all filled bags must have the same weight; (3) bags must easily lend themselves to being lifted from a various rest positions; (4) the center of gravity of each fill bag should remain constant; and (5) the filled bag should be capable of withstanding an impact if hurled 1 mile through space.

2. Robert Barrett is calculating the maximum amount of charge that can be delivered to lunar dust particles, and is discussing electrostatics with Dr. Braden from the school of physics; he has also investigated bearing specifications with several vendors.

3. Brad Anderson has furthered his knowledge of the CMS operating system, and is learning the CAD/AM drafting system for future mechanical drawings.

4. Patricia Gladney concluded that PTFE (teflon) is one of the best materials to withstand degradation due to the moon's wide temperature range and UV radiation; the drawback is its low tensile strength, but this can be remedied by the addition of glass fibers to form a composite.

5. Jerry Cresap has determined that, regarding the closure of the bags, (1) a heat seal is not feasible from a thermodynamic standpoint; (2) adhesive type closures present many problems due to their quasi-liquid nature; and (3) mechanical seals, or pressure seals such as Kwick Seal or Kolo seal, seem to be the best alternatives.

6. Vince Adams has investigated the means of providing the electrostatic charge to the dust particles, and has decided that the "charge transporter" type of power supply is one of the best for charging macroscopic particles.

April 20, 1987 Week 3

MEMORANDUM

To: Mr. Brazell

From: Group V: Adams, Anderson, Barrett, Cresap, Gladney, Wildey

Re: Weekly Progress Report

---

1. It was decided that a design matrix was needed to supply direction to the group's brainstorming and design refinements. A preliminary design matrix for the lunar soil bagging system was proposed. It contained the following system parameters: reliability, automation, minimum energy usage, skitter compatability, environmental compatability, producton rate (not yet finalized), and minimum weight. The preliminary system components were: control system, materials, soil collection/transportation system, bagging system, power source, and soil requirements. In the design matrix method, each of these components will be further subdivided and have its own design matrix created.

2. It was decided that all of the ideas the group was generating needed to be placed on paper. Thus, each member of the group was asked to create two overall design drawings of either new system ideas or already verbalized ideas. Also, each member was to create a design matrix for a particular system and for the overall system. These overall system matrices were synthesized to create the matrix described in paragraph one.

3. Individual Efforts:

David- continued search for digital control systems and is completing design matrix for soil collection system.

Robert- researched on aspects of soil bagging system, including filtering methods and electronics.

Vince- researched into soil transportation systems and their inherent problems. Developed design matrix.

Jerry- further research into suitable material for lunar soil bagging.

Brad- developed design matrix for bag dispensation system and created weekly report.

Patricia- looked into bag needs and created graphic for weekly report.

April 30, 1987

MEMORANDUM

VA DAW PG. RHB

FROM: Vince Adams, David Wildey, Patricia Gladney, Robert Barrett, Brad Anderson, Jerry Cresap

BA JC

TO: Mr. J.W. Brazell

RE: ME 4182, Group 5 Weekly Progress Report

The group spent much time creating and revising design matrices for many of the Sand Bagger components. The completed matrices include soil collection and transport, filtering systems, bag closures, bag materials, and bag release systems. A scale of (0) to (4) was used to rate each of the components in the design matrix, with (4) being the best or most desirable rating and (0) the worst.

The individual ratings were made by group decision and each is subject to change during the design process. The primary function of the desing matrices is to provide a means of comparison between various parameters and to eliminate any bias the group may have for one particular design or system.

The results of the matrices indicate that a rotary brush collection system should be employed with a continuous feed bagging system. The bag should have a valved closure mechanism and be made of a fluorocarbon material such as Teflon. These conclusions are not final, but based on present designs and information available, they appear to be the best solution.

INDIVIDUAL EFFORTS

Vince Adams and David Wildey familiarized themselves with the on-line data base and used it to find additional information on actuators, control systems, and other information the group was having difficulty locating. Vince also represented the group at Fernbank Science Center on Tuesday night.

Patricia Gladney produced several new CAD drawings including detailed designs of the rotary brusher system and the mechanical scraper.

Jerry Cresap worked on the status report and designed a tentative bag closure system.

Robert Barrett produced the overheads for the group's status report and demonstrated the ENERGRAPHICS software to members of the group.

Brad Anderson volunteered to present the group's status report to the ME 4182 class and spent the week working with members of the group preparing for it.

May 14, 1987

MEMORANDUM

From: Vince Adams, David Wildey, Patricia Gladney, Robert Barrett, Brad Anderson, Jerry Cresap

To: Mr. J.W. Brazell

Re: Group 5 Weekly Progress Report

A pie chart was made listing all activities which must be completed during the design of the lunar soil bagging system. Some divisions include controls, soil collection, bagging system, and materials. These groups were divided further into subdivisions, and individual group members were given a subsystem to develop further. This development includes all necessary drawings and calculations and any improvements or modifications which are deemed necessary.

INDIVIDUAL EFFORTS

David investigated fuel cells and redrew the bagger platform for the current design configuration.
Patricia and Jerry decided on a continuous bagging system and developed a tentative design. Patricia also worked on CAD drawings.
Brad did research on fuel cells and is also looking for information on micro-processors, actuators, and bearings.
Robert is learning to use CADAM and is doing calculations for the collection time for different brush sizes.
Vince continued to use the on-line reference system and is working on drawings for the new design configuration.

May 21, 1987

MEMORANDUM

FROM: Group 5, Lunar Soil Bagging System
Vince Adams
Brad Anderson BLA
Robert Barrett RAB
Jerry Cresap JC
Patricia Gladney PGS
David Wildey DAW

TO: Mr. Brazell, ME 4182

RE: Status Report, week # 7

This week the group considered a design change. The change is to use a two (2) brush system rather than a three (3) brush system. All indications are that the two brush system will simplify the design of the system. From preliminary calculations the two brush system be able to cover the same amount of area as the three brush system given the same amount of time. The reason for this is that the brushes can be wider and they can make a longer reach. We are currently considering making the length of the the brush stroke the same as the width of the collection platform.

Brad is continuing to research fuel cells and actuators both in the library and previous projects.

Patricia is working on a collection system for a two brusher system.

David is teaching himself CATIA, researching fuel cells, and structural materials.

Robert is calculating the collection rate for a two brusher system vs. a three brusher system.

Jerry is designing a bag closing mechanism for the two brusher system.

Vince is working on the design of the brushes and the booms for the collection system.

May 27, 1987

MEMORANDUM

FROM: Lunar Soil Bagging System. Group 5.
Vince Adams
Brad Anderson
Robert Barrett
Jerry Cresap
Patricia Gladney
David Wildey.

TO: Mr. Brazell, ME 4182

RE: Status report, week 9

This past weekend the group built a model of skitter. The rest of the week has been spent developing the parameters of the final design. This included specifying motor sizes, member sizes, materials, and part sizes, etc.

During the past week the individual efforts of the group members are as follows.

Robert Calculating hardware specifications including materials and motors. Checked some of the CADAM drawings and calculations.

David Developing overviews of the bagger on CADAM. Specifying materials and members.

Brad Calculating hardware specifications including materials and motors. Checked some of the CADAM drawings and calculations.

Patricia Worked on skitter model. Researched materials.

Vince Worked on skitter model. Checked some of the calculations.

Jerry Redesigned the bagging system from top to bottom. He has also redesigned the bag. and worked on the model.

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